JOURNAL OF

ENGINEERING EDUCATION

Engineering for the Future — J. A. Hutcheson — 602

Engineering Student Dropouts—a special committee report — 611

The Humanities in Engineering Education—four articles — 636

Mechanics Division Bulletin — 654

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THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

APRIL, 1960 Vol. 50, No. 8

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1960 ANNUAL MEETING, PURDUE, JUNE 20–24

Do You Know

► That the Annual Meeting program for Purdue will be one of the best? The International Relations Committee has three top-flight speakers for its program on Latin America, the Mathematics and Physics Divisions have a joint program on computers in engineering; and the Secondary Schools Committee has a double-header program on successful state guidance programs and in-college guidance. These are some of the programs of "across-the-board" interest in addition to the General Sessions.

► That the "Machine Design Manufacturing Bulletin" is a publication of the Mechanical Engineering Division? It is published four times a year and has been published for 26 years. After that length of time it still costs only $1.00 per year, the same as it always has been. Increased costs, however, have made it necessary for the Editor to make a plea for additional subscriptions and for additional contributions of $1.00 per subscriber. The purpose of the publication is to provide a means for the exchange of ideas among those who teach courses related to machine design. Send your subscription and $1.00 ($2.00 preferred) to the Editor, Lee Harrisberger, Mechanical Engineering Department, North Carolina State College, Raleigh, North Carolina.

► That there seems to be a marked improvement in the newsletters of the various Divisions supporting them? This is a good sign and it is hoped that those of you who appreciate the communications so inform the "volunteer" editors and aid them in presenting interesting material for distribution. The reason for this improvement and increased interest perhaps results from the fact that Division budgets have been increased moderately to include this type of activity. Of course, the reason this can be done is the general improvement in Society finances which has been developing during the past few years. Continued improvement also means there must be continued growth in membership! So take a look about you, pick your man, and get him to sign up. Your YET representative and your Dean have membership application blanks, and you occasionally also will find them in the JOURNAL. We are lagging behind the past three-year rate.

► That "Symposium on Education in Materials STP 263" now can be purchased from ASTM? This is the publication resulting from the ASTM–ASEE Symposium held last June. The authors of the papers are K. B. Woods, F. L. LaQue, W. T. Alexander, M. F. Wood, E. A. Walker, Glenn Murphy, G. B. Warren, and H. A. Lepper, Jr. ASTM and ASEE members may purchase the 60-page hard cover book for $1.60; others pay $2.00. Orders should be placed with ASTM, 1916 Race St., Philadelphia 3, Pa.

► That a Study Conference of Sanitary Engineers and Scientists on the Improvement of Graduate Curricula for Sanitary Engineers is to be held at the Massachusetts Institute of Technology on June 28 to 30, 1960? The Conference will be held at MIT, which is acting as the physical agent for the American Sanitary Engineering Intersociety Board, Inc. This NSF grant of $15,000 is the first made for a study of a graduate curriculum. Rolf Eliassen of MIT and H. B. Gotaas represent ASEE on the Planning Committee.

► That E. P. Lange resigned as Secretary of EJC to become Secretary of AIIE, effective March 1, 1960? L. K. Wheelock is Acting Secretary, pending final action by EJC's Executive Committee. Roy has been Assistant Secretary of EJC and Executive Secretary of the Engineering Manpower Commission. Congratulations and best wishes are extended to both.

► That a study made to determine the extent of duplication of membership in the Engineers Joint Council by virtue of the fact that certain engineers are members of more than one member society

indicates that the duplication is at least as great as 5 to 6%? The study was made by the Vicksburg Branch of the Mid-South Section of ASCE. Random samples of names were selected from the directories of twelve of the sixteen member societies; directories of the remaining four were not available. But the duplication figure arrived at for ASEE is 48%. If the non-engineering members and those in areas not covered by the twelve societies studied are deducted from ASEE's membership it appears that the percentage increases to about 60.

► That the Engineering Mechanics Division of the American Society of Civil Engineers is sponsoring a "Theodore Von Karman Award"? N. P. White of the University of Massachusetts is Chairman of the Award Committee. Contributions are being solicited and should be sent to H. T. Larsen. Checks should be made out to Harold T. Larsen, ASCE, and mailed to him or to N. P. White. It is hoped the first award can be made at the October meeting of ASCE.

► That each year the American Association on Emeriti sends out an "Emeriti for Employment" publication in February? Supplements follow as needs arise. Professor Constantine Panunzio, President of the AAE, reports that very few engineering professors enroll and that there usually is no trouble in their receiving satisfactory employment. Those of you who are Emeriti and have the vim, vigor, and vitality that the rest of us should have should get in touch with the AAE, P. O. Box 24451, Los Angeles 24, California.

► That Vol. I, No. 1, of *Technology and Culture,* published by the Society for the History of Technology, looks very interesting? An explanatory opening article by Dr. Melvin Kranzberg states, "For the first time an effort is being made to bring together the engineer, the scientist, the industrialist, the social scientist, and humanists to promote the study and interpretation of developments which are of mutual interest and concern." The address of the Society is Room 311, Main Building, Case Institute of Technology, Cleveland 6, Ohio. Membership costs $8.00 per year.

► That engineers are better educated and better grounded than ever before, but probably aren't as aware of world conditions as they should be? The rapid elimination of time and distance and the terrific rate of change occurring introduces a world influence and an international integrated living not previously dreamed of. These are two of the observations gleaned from the recent College-Industry Conference. Another item coming up time and again was the importance of "recognition" to the engineer choosing to remain in technical work rather than going into management. Salary isn't the whole story; a significant title recognizable in the community cannot be overlooked.

► That newly employed graduates have left jobs because they felt they were in the wrong business, were not challenged by their jobs, wanted more pay, or preferred to live elsewhere? The complaints of employers are that new men expect too much too soon, do not like routine training assignments, lack specific personal goals, and do not understand the business world. The annual report on "Trends in the Employment of College and University Graduates in Business and Industry," by F. S. Endicott, suggests more careful screening of applicants, more challenging and interesting assignments, and more personal recognition; it also implies that the colleges are partly to blame for the unrealistic attitudes of graduates, and that a closer touch with practical situations should be maintained by instructors.

► That here is something to think about? "I deplore the proposals advocated at certain quarters to codify more rigidly the number of student-hours assigned to each professor in the name of economy so tuition charges will pay faculty salaries. I am all in favor of economy and balanced budgets, of course; colleges cannot live long on deficits. But a college which tries to operate like a

factory is doomed to intellectual decay . . . and will soon be in a state where its death is devoutly to be desired." These statements were made by Dr. L. A. DuBridge, in an address given at the annual meeting of the American Council on Education.

► That engineering and sciences will be among the fastest growing professions? "Twenty years ago only one scientific or technical worker was employed for every 100 people in the labor force; today there is one for every 32 workers. Technicians who work with and give technical support to engineers and scientists will also be very much in demand. Employment in these technician occupations has shot upward during the past two decades. By 1957, the number of technicians employed had just about caught up to that of engineers. In 1970 there will probably by more technicians than engineers in industry and government agencies." These statements come from "The Manpower Outlook for the 1960's—Its Implications for Higher Education," by Newell Brown, Assistant Secretary of Labor for Employment and Manpower, as published in Higher Education for December 1959.

► That "Communications in Research" was the theme of the English Division's "day in industry" at the Pittsburgh meeting? Some of the ideas expressed there were: In spite of a reputation to the contrary, engineers are not hopelessly bad communicators; engineers experienced in the same discipline find that a precise technical vocabulary promotes communication, although it may be unintelligible to the untrained. Those who can communicate best are most often those who grow the fastest and to the greatest stature. Because of the political importance of the private citizen, scientists must communicate clearly to the layman. The growth of the engineer and of his company depends on management's ability to communicate with consumers and the general public. Those who give the engineer the tools of expression make possible his fulfilling three primary responsibilities: to his country, to his profession, and to himself. All teachers and instructors should keep hammering away at the tendency to get away from simple language; a reader should not have to reread each sentence to understand what the writer is trying to say. Technical writing, making facts and figures interesting to the layman, is an art, the value and need of which too many students do not realize. English composition classes can teach human relations and can develop creative thinking.

► That information regarding teaching opportunities abroad can be obtained from the Advancement and Placement Institute? API publishes a monthly nonfee placement journal called *Crusade for Education* and a recent issue is the annual "international" issue devoted to foreign positions available in September of 1960. Copies are available at the offices of most deans and university libraries, and also may be purchased for $2.00 from API, Box 99-M, Station G, Brooklyn 22, New York.

► That the Industrial Engineering Division is sponsoring a Summer School at Purdue on June 18 and 19, 1960? The program is designed as a forum for the interchange of ideas on the best way in which to integrate new material to the subject matter taught in industrial engineering. Mathematical requirements, statistical requirements, psychological developments, physiological developments, sociological developments, systems analysis, systems simulation and incorporating frontier areas are the topics to be considered. The registration fee is $3.00 and it should be sent to Professor H. T. Amrine, Department of Industrial Engineering, Purdue University.

► That your friends will expect to see you, your wife and your children at Purdue on June 20–24? When you get that Preliminary Program don't forget to show it to *all* the family!

W. Leighton Collins
Secretary, ASEE

Engineering for the Future

J. A. HUTCHESON

Vice President—Engineering,
Westinghouse Electric Corporation

In view of the speed of present technological events, one cannot say with certainty what the future will be like. Nor can one foresee in detail the countless engineering problems to be solved in bringing that tomorrow into being. But one can and should make some informed guesses as to where the major problems lie. And one can and should begin now to concern himself with their identification and solution.

As any engineer knows, the process of extrapolation provides a means of predicting what will happen in a given situation based upon what already has occurred. This process is not infallable, but it is a useful and rational approach to problem solving.

By extrapolation, then, we can look at some of the major problems of today and can expect them to provide a clue to the probable engineering problems of the future. I should like to suggest three broad categories of endeavor wherein I think the engineer of tomorrow will find his most challenging and socially significant problems. I am sure that the solution of these problems will require all the competence and foresight and versatility that the engineer can command. And I am equally sure that the answers will require more than a casual amount of devotion to duty and dedication to the task at hand.

My conviction is that in the years to come engineers must become increasingly ingenious in (1) the development of ways and means for obtaining the basic raw materials from which our goods will be made, (2) in the development of new sources of energy, and (3) in the development of new ways to increase our productivity of the goods we want and need.

Presented at the 67th Annual Meeting of ASEE in Pittsburgh, June, 1959. Recommended by the Mechanical Engineering Division.

Raw Materials

It is obvious that we and all peoples of the world will require basic materials in ever increasing abundance. It is equally obvious that as we take these materials from nature we deplete the supply. Consider, for example, two common materials—copper and iron.

In the 18th century it was considered impractical to use copper ores in which the copper content was less than 13%. By 1900 the average grade of copper ore being processed was about 5%. By 1950 the average grade of ore had dropped to 0.9% and ore containing as little as 0.6% was being processed. Although our copper consumption is actually much less than that of iron, to obtain the copper we use today, it is necessary to handle each year as much copper ore as the annual production of iron ore in the United States.

The situation with iron is similar. At the present time our iron-producing facilities need ore containing about 50% iron. At our present rate of usage, the supply of ore of this quality available in the United States will last some 15 years. Since 1935 engineers have been developing processes for the enrichment of lower grade ores, starting with those having as little as 35% iron. Again, at our present rate of consumption, ore of this quality will last no more than an additional 25 years.

As we are forced to lower-grade sources of raw materials, we must expend relatively larger amounts of energy in their conversion into useful form. We

must handle ever-larger quantites of materials; we must dig ever-deeper into the face of the earth; we must transport our ores from more distant points. All of these alternatives require energy in abundance.

This leads to the second problem which must receive the attention of our engineers: the production of increasing amounts of energy.

Energy

There is no better illustration of man's insatiable demand for energy than his use of electric power. In 1958, there was generated in this country 737 billion kilowatt-hours of electrical energy. According to the best estimates available, ten years from now that figure will grow to one- and one-half trillion kilowatt-hours.

Such astronomical figures have little meaning except, perhaps to those who are charged with figuring out the public debt. Therefore, to make them more meaningful, let us consider simply the growing residential consumption of electricity, omitting from our thinking for the moment all the tremendous quantities of electric power used by commercial enterprises and American industry. Let me interject, however, this thought: It requires as much electric power to manufacture one pound of aluminum as it does to power the average American homes for one day, and last year the aluminium industry produced 3,131,000,000 pounds (1,565,000 tons) of the metal.

Of America's 51,100,000 homes, some 49,400,000—nearly 97%—are wired for electricity. And of these wired homes, about 98% have refrigerators, 96% have radios, 91% have electric washers, 89% have television sets and 12% have air conditioners.

These figures are immensely interesting. More homes are equipped with radios than with telephones; more have television sets than bathtubs. If all these television sets are turned on at one time, such as happens when the President is to appear, the electricity required to power them is equal to one-tenth of the total generating capacity in the nation. And if every home that has a television set were also to be equipped with a home air conditioner—and some people think this day is coming soon—the power required to operate all of them at one time would equal our present ability to generate electric power.

No one can point to a single circumstance which would lead us to doubt that this demand for electric power will continue, and at an accelerated rate. Already electricity permeates almost every aspect of human endeavor. And, because it is the one source of energy that is easy to make, easy to transport, easy to use and easy to control, it will continue to be exploited in spectacular fashion. Today only a small percentage of our homes are heated with electricity; my conviction is that in the foreseeable future electricity will be the standard method of heating and cooling them, and this may very well be done with no device yet in existence. My conviction also is that many of those in this audience, perhaps myself included, will see the day when the electrically driven automobile will be the rule rather than the exception.

Our scientists and engineers are seeking new ways to obtain electric power from a variety of prime sources of energy. But most of it today comes from the burning of fuels deposited in the earth countless millions of years ago. In fact, at the present time, essentially all our energy, for whatever purpose we use it, comes from fossil fuels, including coal, gas and petroleum. Together these sources account for 96% of our energy supply. Almost all the remaining 4% comes from water power.

It is pertinent to look at the world resources of fossil fuels. We find that estimates of these reserves vary widely, so to make use of them, I have chosen to take both the most optimistic and the most pessimistic estimates. Thus, if we translate all fossil fuels into the equivalent number of tons of coal, the most optimistic estimate of the world's resources places them at 8,000 billion metric tons; the most pessimistic estimate is ten times smaller. At the present world rate of consumption of energy, the time for exhaustion of the world's reserves is 4,000 years

optimistically, or 400 years pessimistically.

It must be emphasized that these estimates are based on consumption of energy by the peoples of the world at current rates. These figures allow nothing for increase in world population or for a rising standard of living throughout the world. Today's world population is over 2.6 billion. By 1980, United Nations estimates place it at 3.6 billion. Suppose a world population of even 3 billion wanted to achieve a standard of living comparable to that which you and I enjoy today. In such case, the optimistic estimate of our fuel reserves drops from 4,000 to 230 years, and the pessimistic estimate drops from 400 to 23 years.

One cannot predict what factors will affect this situation. But it simply is being realistic to recognize that the trend is such that by the end of this century the problem of a supply of energy to maintain our standard of living well may be acute. Whatever the answer may be—solar energy, nuclear energy by fission or fusion, or sources of power yet to be discovered—certainly man's voracious, frequently wasteful appetite for energy must be of increasing concern to the engineer of tomorrow.

These two areas I have mentioned, raw materials and available energy, constitute the basic ingredients of a nation's economy. Translated into airplanes and soap and tractors and TV sets, they fix our standard of living. Translated into missiles and radar and thousands of other fantastically complicated products, they determine our changes of survival. Perhaps the engineers' most critical task in the years immediately ahead will be to prove that in this nation, under our economic system, we can meet both obligations simultaneously. Ever-increasing productivity of the things we can and must have, is a third major problem area of tomorrow's engineer.

Productivity

I have said that an exploding world population is a contributing factor to the insatiable demand for raw materials and useful energy. The same holds true for the products of industrial production. We must bear in mind, however, that these are not linear relationships. The population of the United States has little more than doubled since the turn of the century. But the amount of steel in use in this country has doubled every 20 years; petroleum production has doubled every 15 years; and the production of electrical energy has doubled every 10 years since 1900.

Similarly, our demand for goods and services is growing at a rate which far outstrips our rate of population growth, and no one can detect a lessening in our collective desire to increase it further. Things which two or three decades ago were considered luxuries, or were not available at any price, are today commonplace and thought of as necessities. I ask you only to consider such modern, diverse "necessities" as electric refrigerators, central heating, automobiles, hi-fi sets and outboard motors.

But our labor force—those who must produce these goods and services—grows no faster than the population. In the next ten years it has been estimated that this labor force will increase by about 18%. During this same period, to meet foreseen demands, our production capacity must increase by some 50%. It is obvious that if we are to continue to have the things we want and need, each laborer must become more productive. This does not imply that he must work harder or longer. Rather, it means that he must have more and better tools, more power at his command, so that he can produce more in a given time with the same or less effort.

The provision of these tools has been called automation. Automation is not really new. Rather, it is a present-day word to describe a process that has been going on for a very long time, ever since man's need for a product began to outstrip his ability to build it by hand. Consider, for example, the manufacture of electric lamps, or what most people call light bulbs. My company makes these at the rate of ten a second, day in and day out. They are made by machines with virtually no human effort, and this has been going on for decades.

For this reason, they have decreased in cost ever since they were invented and one shudders to think what one would cost at today's labor rates if it had to be assembled by hand.

The point I am making is that this technique we now call automation has been evolving over a long period of time, and has brought vast benefits to every segment of our society. There seems to be little doubt that it must and will continue to develop if we are to maintain our own progress and security, and to help bring to the underprivileged millions of the world the fruits of a better way of life.

As automation continues to be applied to industrial production, we can expect to hear, in increasing tempo, the variety of opinions that always have surrounded it. Like most scientists and engineers, I would not attempt to pose as an expert upon social problems. But, speaking as a scientist and engineer, I feel one observation is in order.

It is this: That whatever one's personal emotions may be, they will not seriously affect the ultimate course of automation or, for that matter, any other large-scale scientific or technological development of the future. In discovering the secrets of nature, and in applying them to man's progress, the scientist and engineer does not pick and choose among the truths she chooses to reveal. As George R. Harrison, Dean of Science at Massachusetts Institute of Technology, has so aptly pointed out, ". . . one takes them as they come and uses them as one can." No amount of wishful thinking will hold back the scientific knowledge that makes possible improvements in our technology, whatever form these improvements may take.

It may be pertinent to point out another fact apparent to most engineers: In the long run, scientific developments often produce the very opposite effects from those commonly feared in the public mind. Automation is a case in point. It turns out that the fields in which automation is being most rapidly applied are the very ones where employment is greatest. The employment comes, not in spite of the machines, but because of them. It seems to be difficult for many people to grasp the important truth that social and economic gains—shorter working hours, fuller employment, greater purchasing power and the like—are the *result* of greater productivity. They are the *consequence* of abundance, not the *cause* of it.

The growing demand for basic raw materials, the need for increasing amounts of energy, the development of ways to increase productivity—these, then, are three of the major problem areas to be faced by the engineer of tomorrow. I do not suggest that the engineer alone can solve all the problems inherent in these areas; it will require the ingenuity and dedicated effort of many people, professional and nonprofessional alike.

But the engineer will play a key role. Dr. Lyman Bryson has described the engineer as the one who intervenes for human purposes in the processes of nature. "In all civilization," Dr. Bryson says, "you attempt to put the educated finger into the machinery of nature and make it do things that would otherwise not happen. So, in a sense, the engineer represents civilized man or the agent of civilization. He is in a powerful position in our society."

I would agree with Dr. Bryson that the engineer is a key figure in our society. I think he will continue to be. But, in fulfilling the key role he will play in the world of tomorrow, he cannot be content to exemplify the traditional "dyed-in-the-wool" engineer so familiar in the past.

The engineer of tomorrow must be many things—alert, competent, dedicated, well-trained. But if I were to select the single attribute he must possess in far greater measure than his counterpart of yesterday and today, I would cite "versatility."

The pace of science already demands it. A few years ago we saw progress in atomic knowledge create a whole new field of engineering in less time than it takes to put a single engineer through college. I recall in our own organization how almost overnight, a small handful of scientists—primarily physicists—were suddenly transferred from the pursuit of the-

oretical nuclear physics with a Van de Graaff generator and given the formidable task of bringing into being the power plant of a nuclear submarine.

Today, a roughly similar situation exists in space technology.

So fast are we moving scientifically that frequently the only person competent to guide the development of a useful device is the man who discovers the new knowledge upon which it is based. Conversely, one finds that the only persons capable of competently carrying through a development are those conversant with the knowledge and skills unique to scientific research.

If you interpret this to mean that I see a breaking down of the traditional "bricks and mortar" of the engineer and the "ivory tower" of the scientist, that interpretation is correct. No longer can I find any really valid reason for perpetuating arbitrary distinctions between the "research" of the "scientist" and the "development" of the "engineer." From a practical, administrative point of view, one cannot really tell where one leaves off and the other begins. And if there is any real value in theoretically fitting them into tight, mutually exclusive compartments, I have been unable to detect it.

Meaningful distinctions between "basic" and "applied" research are equally difficult to establish. More often than not, the problem involved is simply one of semantics. At the risk of belaboring a point, I might illustrate the difficulties involved by citing the results of a recent luncheon discussion on the subject with one of my colleagues. He took the familiar position that to be "basic," research must be "free," "undirected," "removed from practical application." Before our discussion ended, my colleague found himself in the uncomfortable position of defining as basic any research so far removed from reality as to be absolutely useless. I hastened to point out that under such a definition I would be hard put to justify to our Board of Directors a considerable portion of our own research budget.

In looking at tomorrow's engineer, I do not suggest that he is destined to lay aside his traditional function of creating the technological environment of the future. This he will continue to do. But in doing it, he must of necessity exhibit a new degree of versatility in outlook, training and experience.

Perhaps an example, with which I have personal experience, will illustrate what I mean.

Since 1822, a phenomenon known as the Seebeck Effect has been in the reservoir of scientific knowledge as an interesting but not very useful bit of information. The Seebeck Effect says that an electric voltage can be generated in two unlike pieces of metal when they are jointed together and their junction is heated. About the only usefulness the engineer has been able to find for this phenomenon over the years is in measuring temperature, for such a junction typically produces only a few thousandths of a watt of electric power at an efficiency of a small fraction of 1%.

For more than 20 years now, we have been seriously studying this phenomenon, called thermoelectricity, at the Westinghouse Research Laboratories. And about three years ago we reached a level of understanding which suddenly transformed it from a scientific curiosity into one of the most exciting developments to come along in many years. I am rather proud of the fact that the multi-million-dollar research and development program now going on nationally in thermoelectricity can be very largely traced to a handful of scientists in our own research organization.

I cannot detail here all the things that have happened to Mr. Seebeck's milliwatt, 0.1% efficient thermocouple within the past three years. But I can report that we now are developing a 5,000 watt thermoelectric generator and have achieved efficiencies quite comparable to those encountered in the average automobile.

Thus, in a remarkably short period of time, thermoelectricity is passing from the researcher to the engineer. But in the transition, we find that many of the pertinent engineering problems are quite alien to conventional engineering concepts. For example, the engineer of heat engines has traditionally conserved the

maximum amount of heat energy inside his engine so that it would be available to do useful work. Heat which passed through the walls of the engine represented wasted energy and loss in efficiency.

Suddenly, in thermoelectric heat engines, he faced the fact that to work at all, heat *must* pass through the walls of the engine. This was completely unconventional, and no engineer could expect to solve the thermodynamic problems of thermoelectric devices without some understanding of the mechanisms of heat transfer, electrical conductivity, and related characteristics of semiconductors and other solid state materials. Some of our engineers, therefore, rapidly entered the intellectual domain of the solid state physicist.

In engineering for the future, such versatility will be "par for the course." And if the young engineer thinks that in the broad problem areas we have discussed today there are no intriguing opportunities to display this versatility, I must suggest that he consider the following two propositions:

Scattered across some 14 million square miles of ocean floor off the southeastern coast of the United States and between South America and Tahiti, are some 200 billion tons of rock-like "nodules" containing, some estimates say, up to 40 billion tons of manganese and one billion tons each of copper, nickel and cobalt. These amounts are about 1,000 times the world's reserves of cobalt, 150 times the reserves of manganese, 20 times the reserves of nickel and 6 times those of copper. It has been estimated that this vast mineral resource, much of it under more than 15,000 feet of water, may be worth at present prices up to $1.5 million per square mile, and have a total value of some 10 thousand billion dollars.

The second proposition is this:

One hundred tons of granite, one of the most abundant of rocks, contain, in addition to other useful elements,

8	tons of aluminum
5	tons of iron
1200	pounds of titanium
180	pounds of manganese
70	pounds of chromium
40	pounds of nickel
30	pounds of vanadium
20	pounds of copper
10	pounds of tungsten, and
4	pounds of lead.

Also present in these 100 tons of granite are 4 grams of uranium and 12 grams of thorium; and the energy available within them is enough to process the entire mass of rock and obtain from it the quantities of materials I have described. All we need is the know-how to do it.

Perhaps, in the first decade of the 21st century, challenges such as these may have become part of the standard review course in high school science. If so, we cannot doubt that problems equally challenging and equally significant will confront the young engineers of that generation.

For man, being the kind of being that he is, cannot stop the discovery of the facts of nature even if he tries; neither can he, if he would, interrupt for long the application of that knowledge to his purposes.

That there never will be an end to the knowledge man has at his disposal is, at once, among the most ennobling and frightening of all great truths. It suggests that we who labor in the cause of science must do more than simply contribute to the fund of human knowledge. We must, with increasing urgency, strive to make man's use of it wise and humane and purposeful—worthy of the intellect which brought it into being.

This well could be the engineer's ultimate challenge in any generation.

Engineering at Purdue

A Brief Account of What, Where, and When of Engineering at the Host Campus of the 1960 Annual Meeting

As a Land-Grant college, Purdue University was founded primarily to teach the agricultural and mechanical arts. An engineering curriculum, therefore, has been one of the major offerings of the University since its doors were first opened to students in 1874. The first engineering degree, in civil engineering, was awarded in June 1878.

In 1879 the School of Mechanics was established, becoming the School of Mechanical Engineering in 1882. In 1888 Electrical Engineering was organized as a separate school. Chemical engineering was established as a course of study in 1906, and in 1911 was made into a separate school. Metallurgical engineering was added to the degree offerings of this school in 1938, and the name changed to the School of Chemical and Metallurgical Engineering. In 1959 this marriage was dissolved, and Purdue now has separate Schools of Chemical Engineering and Metallurgical Engineering.

As early as 1926, Aeronautical Engineering courses were offered as options in Mechanical Engineering. In 1942–43 four years of Aeronautical Engineering as an offering of the School of Mechanical and Aeronautical Engineering appeared for the first time. The School of Aeronautics, including the curricula of Aeronautical Engineering and Air Transportation, was set up as a school in 1945. In 1955 Air Transportation became a part of the School of Industrial Engineering and Management, and the school's name was changed to the School of Aeronautical Engineering.

The Department of Engineering Mechanics, formerly part of the School of Civil Engineering and Engineering Mechanics, was set up as a separate division in 1954, and its name changed to the Division of Engineering Sciences. Agricultural Engineering offered jointly by the School of Agriculture and the Schools of Engineering was started in 1946. In 1955 a School of Industrial Engineering and Management was formed. With the advent of a School of Industrial Management in 1958, this school was dissolved, but the Department of Industrial Engineering still remains as a separate department within the Schools of Engineering.

Associated with the various schools and

Students in the School of Civil Engineering are shown experimenting with a design for a shell roof structure.

departments of technical instruction are student branches of all the major national technical and scientific societies.

Curricula

Undergraduate instruction in aeronautical engineering, agricultural engineering, chemical engineering, civil engineering, industrial engineering, mechanical engineering, engineering sciences, and metallurgical engineering leads to the degree of Bachelor of Science. Purdue has recently established a new Department of Nuclear Engineering and offers courses in Nuclear Engineering from two categories: 1) introductory terminal courses for engineering students, and 2) specialized, graduate courses for those students preparing for careers in nuclear engineering research and development.

All Schools of Engineering and the Division of Engineering Sciences offer the M.S. or Ph.D. In addition to the schools and departments of instruction, the Schools of Engineering maintain the Engineering Experiment Station, which conducts research in the various fields of engineering, and cooperates with engineering societies, industries, railroads, utilities and the government. Major contributions in engineering research have been made in the fields of transportation, heat transfer, electric power transmission, materials, gas technology, electronics, and power engineering.

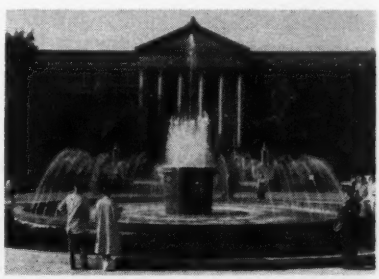
Places to Visit

A number of the engineering buildings and facilities on the Purdue campus merit inspection by ASEE members. Of particular interest will be the William Freeman Myrick Goss Library of the History of Engineering. The Goss Library was established in 1928, when Purdue University received the personal library of William Goss, Dean of Engineering at Purdue from 1879 to 1907. The library, now housed in the Engineering Administration Building, contains over 5,000 volumes and is probably the most complete library of engineering history available in any university in the nation.

Also of interest will be the Nuclear Engineering Laboratory housed in the Duncan Wing of the Electrical Engineering Building. Among the equipment of this laboratory is a sodium-potassium high temperature heat transfer loop, a boiling water loop, an expotential assembly, a gamma-irradiation facilitiy, an irradiated fuel processing laboratory, and an analog computer used as a reactor simulator.

The Herrick Laboratory, home of Purdue University's new Center for Refrigeration and Climate Control, is another point of interest. This is a joint facility of the School of Mechanical Engineering and the Agricultural Experiment Station. It houses several environmental chambers in which temperature, humidity, light intensity, and air movement can be fully controlled. These chambers are designed for fundamental studies in animal physiology. In addition there is a splendidly equipped laboratory for engineering research into the problems of refrigeration, air conditioning, and climate control.

The Theromphysical Properties Research Center is housed in the Mechanical Engineering Annex. This data center, activated in 1957, has as its aims the collection, analysis, correlation, and dissemination of information about the thermophysical properties of matter and the provision of unique facilities and opportunities for graduate study and research on thermophysical properties. At present the center has stored in its files nearly 23,000 abstracts of articles of basic information on thermophysical properties,



"Purdue University Fountain of Learning." This scene shows the Memorial Fountain recently installed in front of the Administration Building on the Purdue campus.

taken from nearly 12,000 technical and scientific journals.

Other laboratories and facilities of interest are the Rocket, Jet Propulsion and Gas Turbine Laboratories, the Highway Research Laboratories of the Joint Highway Research Project operated by the School of Civil Engineering in cooperation with the State Highway Department of Indiana, the Aircraft Structures and Dynamics Laboratory, and many others, far too numerous to be listed.

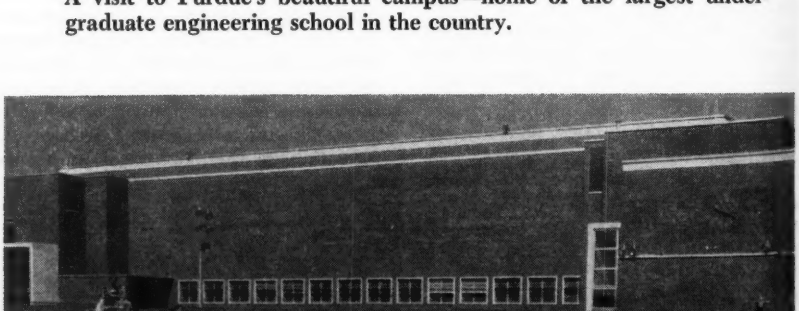
ASEE members may be assured of a warm welcome by members of the instructional and research staff of Purdue University's Schools of Engineering. They are invited to tour and inspect the laboratories mentioned in this article as well as the many other instructional and research facilities on the Purdue campus.

Highlights of the Purdue Meeting

Interesting and informative programs for educators, engineers, industrialists, scientists, women, and children.

- ★ The Role of ASEE in Latin American Relations.
- ★ The Impact of Space Technologies.
- ★ Development of Engineering Faculties.
- ★ Long Range Training and Development Needs of the Engineer.
- ★ The National Survey of Technical Institute Education.
- ★ Methods of Teaching.
- ★ High School Preparation for College.
- ★ An Evaluation of Cooperative Education.
- ★ The Future of Industrial Engineering.
- ★ Workshop on Solid State Electronics.
- ★ Review of Events in Washington.

A visit to Purdue's beautiful campus—home of the largest undergraduate engineering school in the country.



Shown above is the Coeducational Recreational Gymnasium with the outdoor swimming pool in the foreground.

Engineering Student Dropouts

Report of the ASEE Sub-Committee on Dropouts of Engineering Students

NEWELL L. FREEMAN
A. PEMBERTON JOHNSON
DONALD H. MOYER
DONALD S. BRIDGMAN, CHAIRMAN

This report is based on responses to a questionnaire addressed to the Deans of Engineering in May, 1958, received from 92 institutions; responses to a question concerning increased attrition in the current academic year as compared with other recent years included in the January 1959 survey of the Engineering Manpower Commission primarily on freshman engineering enrollment trends; visits by the Committee Chairman to 7 institutions in 1958 and 1959; examination of enrollment data compiled by Dr. Henry Armsby of the U. S. Office of Education; and review of some of the literature in this field.

I. Summary

A 1957 U. S. Office of Education study has reported that 39% of the non-veteran single freshmen entering all undergraduate curricula in the fall of 1950 graduated in 4 years from the original institution entered and has estimated that 50% graduated from some institution in 4 years and 60% ultimately do so. More recent data indicate that the latter ratio of 60% now may be about 55%. An earlier Educational Testing Service study of non-veteran freshmen entering engineering curricula in the fall of 1948 reported that 33% graduated in 4 years and 44% in all were expected to graduate in engineering from the institution first entered. Rates very similar to those found by this latter study were estimated for engineering students from data secured by this Committee in its survey of May 1958. Both the E.T.S. study and the Committee's survey included data indicating that 10–15% more of the entering freshmen, after transfer to other curricula, probably would graduate in them. On this basis, the ultimate graduation ratio estimated for all curricula would be approximated in engineering schools.

These results have been obtained from studies of classes graduating in recent years, including some taken from a representative sample of the 1957 engineering class. In addition, however, the Committee has computed more recent gross retention rates for individual classes by comparing their enrollment figures in two successive years; e.g. this year's sophomores with last year's freshmen. Such figures include the transfers to engineering schools from junior colleges and other curricula and consequently are higher than those affected only by the losses from engineering. They indicate what is happening at each class level from one year to the next and their trend over a period of several years seems quite significant.

Such a comparison shows that the ratio of sophomores to the preceding year's freshmen was 79% in 1955, declined to 68% in 1958, and recovered to 70% in 1959. A similar downward trend occurred from 1955 to 1958 in the other classes with stabilization or a small recovery in 1959. A cumulative ratio, which may be obtained by multiplying together the ratios for the four class levels in any year and which represents the ratio between the number of degrees given and the corresponding entering freshmen if the rates for that year held

over a 4 year period, decreased from 62% in 1955 to 44% in 1958 and recovered to 47% in 1959.

The modest improvement in the sophomore-freshman ratio in 1959 as compared to 1958 is only slightly encouraging since the smaller 1958 freshman class presumably included fewer students of marginal interest and aptitude. It is clear that the downward trend in retention rates at each class level up to 1958 has affected markedly the numbers of graduates to be expected from the present junior and senior classes. If relatively high loss rates should continue with smaller freshman classes than anticipated, the result would be severe reductions in the numbers of graduates in future classes.

A special analysis of the freshman-sophomore sequence rates for 1957 to 1958 as compared with those for 1956 to 1957 in individual institutions also has been made. From this, 51 institutions, 33 public and 18 private, with substantially heavier losses in the later year were identified. In these institutions, this retention rate decreased over 10 points as compared with 5 points in all E.C.P.D. institutions. In the public institutions included, the total increase of about 3,800 in number of students lost was slightly more than the total for all E.C.P.D. schools. These generally were very large schools and in addition, they had had a substantially greater increase in freshman enrollments the previous year than all E.C.P.D. schools together.

From 1958 to 1959, the sophomore-freshman retention rate in both the public and private institutions in this group improved appreciably, recovering some 4 points of the 10 point increase in loss rates of the preceding year.

What appear to be the principal reasons for the losses occurring and particularly for their recent increases? The two earlier studies cited and the May, 1958, Committee survey used different classification, but, except for the Office of Education study, financial difficulties were not shown as a major reason, and even in it, such difficulties were given as only one of several factors of about equal importance. The primary reasons, by large margins, given by the Deans responding to the Committee survey were, (a) for losses in freshman year, "students' lack of effective work habits" and their "lack of adequate motivation," (b) for later losses, "students' lack of genuine interest in engineering" and their "lack of ability for advanced subjects." In response to the Engineering Manpower Commission's question concerning attrition, included in its January 1959 survey of reasons for decreased freshmen enrollments, about 50 institutions reported an increase had occurred during the past year and listed "concern about the rigors of the engineering curriculum," "increased interest in other scientific fields" and "reports of diminishing employment opportunities in engineering" as the major reasons for it. A less frequent but still significant reason was "decreased ability to finance an engineering education." In public institutions, the most frequent reason given was "application of higher scholastic standards." This reason and "concern about the rigors of an engineering curriculum" were given most often by the institutions with greatly increased losses in the freshman-sophomore sequence, which replied to the E.M.C. question and indicated increased attrition.

In their response to the Committee's survey question concerning measures to reduce student losses, the Deans most frequently listed "better admissions procedure" as of greatest importance. But both their written responses and other opinion secured from individuals make it clear that only a number of measures, including more effective contacts with the high schools, better college personnel services, and more understanding and stimulating teaching will lead to significant improvement. In spite of admission standards, which, in general, have been relatively high and which have become more rigorous in recent years, the retention rate in engineering does not compare favorably with that in other curricula and, in the past few years, appears to have significantly decreased. Where careful examination of this rate and its immediate trend is not already a matter of routine, such examination is a prerequisite to effective action.

II. The General Situation

A. *Extent of Attrition among Engineering Students*

To provide perspective for the current findings, reference should be made to two other relatively recent comprehensive studies in this area, conducted through follow-up of individuals entering as freshmen to the point of graduation or separation from their original school. In one of these studies, the progress in other institutions of transfer students was included.

The first of these, conducted by the Educational Testing Service, covered 13,000 non-veteran entrants to 101 engineering colleges in 1948. Thirty-three per cent of these entrants, 25% in public and 46% in private institutions, graduated in 4 years or had completed 4 years of a 5-year program in their original institution. Eleven per cent more were still enrolled and expected to graduate, who would increase the total to 44%. In addition, about one-sixth of the original entrants withdrew from engineering, expecting to transfer to other curricula.[1]

The second study, conducted by the U. S. Office of Education, is of principal interest in providing comparative data for students in all curricula, since the only engineering students classified separately were about 800 from 10 institutes of technology. The total sample included over 13,000 non-veteran single full-time entrants of both sexes who entered college in the fall of 1950. Thirty-nine per cent of these entrants, 33% in public and 48% in private instiutions, graduated from their original institutions in 4 years. In the institutes of technology, the corresponding ratio was 42%. The study's report estimated that about 50% of these entrants graduated from some institution in 4 years, about 60% graduated ultimately.[2]

[1] A. Pemberton Johnson, "Graduation, Holdback, and Withdrawal Rates in Engineering Colleges," JOURNAL, Vol. 45, No. 3 (November 1954), pp. 270–73.

[2] R. E. Iffert, "Retention and Withdrawal of College Students," U. S. Office of Education Bulletin No. 1, 1958, Government Printing Office, 1957.

More recent data indicate that the 60% ultimate ratio now may be too high, since the number of 1957–58 first level degrees was about 54% of the number of 1954–55 full-time entrants, 57% for men and 51% for women. In obtaining these ratios, the number of first degrees in medicine, law, theology and a few other similar fields has been deducted from the first-level degree total, in which these degrees are included, since almost all are second degrees for their recipients, who entered college in earlier classes.

This Committee's assignment did not include a longitudinal study of the type carried on by these surveys, with its 4-year follow-up and handling of individual student records by the schools. It did attempt to secure from schools in which the records permitted an approximation of the graduation ratio such a study might give. The results of its inquiry along these lines are shown in Table I.

Reports from a limited number of institutions indicated that from 15–20% of the entrants had transferred to other curricula or institutions. Other evidence indicates that a majority of such transfers graduate.

It may be concluded from these data that from 40–45% of the full-time entrants to engineering schools in recent years have graduated from the institution of original entry, but some 12% have required more than the normal 4 or 5-year period to secure the B.S. degree. Transfers to other curricula or institutions are likely to add another 10–15% of the original entrants to the number receiving degrees in engineering or some other field, making a total proportion of 50–60%. This ratio seems to be of the same order of magnitude as the 57% ratio for men in all curricula given above. It should be recognized, however, that such a ratio for engineering students should be somewhat higher in view of the more rigorous admission standards in most engineering schools.

B. *Reasons for Attrition among Engineering Students*

The Iffert study covering students in all curricula during the Korean crisis

TABLE I

RATIOS OF 1957 ENGINEERING GRADUATES TO ORIGINAL COMPARABLE ENTRANTS IN 59 INSTITUTIONS AND AS ESTIMATED FOR ALL E.C.P.D. SCHOOLS[1]

Type of Control	Number of Institutions	Ratio Total Grads to Freshmen	Ratio Applicable[2] Grads to Freshmen	No. Inst.	Period	
					Normal	Extended[3]
		Survey Sample				
Public	27	51%	38%	21	58%	42%
Private	32	67%	57%	27	82%	18%
Total	59	57%	45%	48	71%	29%
		All E.C.P.D. Schools				
Public	78	48%	36%[4]	No estimate attempted		
Private	64	65%	55%			
Total	152	53%	42%			

[1] A few institutions reported for the 4-year period 1954 to 1958. For institutions with 5-year programs, entrants of 1 year earlier were used.

[2] After deduction of graduates from other curricula, junior colleges, and those securing degrees through evening study. Transfers from other engineering schools were not deducted. The remainder should give the number of graduates from the comparable freshmen in this group of institutions.

[3] Graduated after more than 4 years of academic work, in addition to summer make-up courses (more than 5 years of programs in that length).

[4] Using the same ratios of total graduates to freshmen as in the survey sample. (For example $48\% \times 38/51 = 36\%$.)

(1950–54) found entry into military service as the most important reason for separation from college according to the students' reports, followed closely by academic difficulties and financial difficulties, with lack of interest in studies of nearly equal importance.

The Educational Testing Service report for engineering students indicated that, of all separations, one-quarter were dropped for academic reasons, almost an equal proportion withdrew with failing standing, and most of the remainder withdrew in good standing. Of all withdrawals, about one-half expected to change curricula, with other reasons scattering.

This Committee's survey requested the deans to give their opinions concerning reasons for losses. Table II shows its results.

The problem of legal requirements for admissions, of course, was confined to the publicly supported institutions. Those institutions also place somewhat greater emphasis on the lack of adequate motivation and inadequate high school counselling as reasons for loss in freshman year and on financial difficulties in the later years. Generally, however, of the studies cited, only that by Iffert for the Office of Education indicated that financial problems were one of the major reasons for dropout.

Another part of the Committee's inquiry sought information concerning the mental ability level, as determined by aptitude tests, of the engineering freshmen and the trend in this respect over the past few years. Returns were too limited and varied in character to permit any quantitative summary. They tended to confirm, however, the general impression that the ability level of such freshmen was appreciably higher than that of freshmen in other curricula and that this level was rising as the result of tightened admission standards. In a few institutions, the level of ability reported was extremely high. The effort in the Committee's survey to secure the deans' opinions concerning the all-round calibre of the students dropping out was far from successful because of lack of precision in the question on this point. The usable replies secured indicated that in the majority of the public institutions, relatively few of the dropouts were con-

sidered to be potentially competent engineers. Other public institutions, however, and the majority of the private institutions indicated that a substantial proportion of such men did have the intellectual ability needed but that many of them lacked the determination, interest and drive to succeed.

In general, the evidence secured portrays a broad pattern about as follows:

1. Although the admission procedures of a majority of the institutions provide a basis for selecting students with the requisite mental ability, we are not yet capable of identifying drive, the extent of interest or the ability to overcome severe obstacles.

It appears that many students have never recognized the necessity for hard work, have failed to develop habits of genuine work and have had no experience in facing and overcoming failure. In addition, students often have extremely inadequate knowledge of the demands of the engineering curriculum or the characteristics of the engineering profession. At least until 1958, too many were attracted to the field by the impression of severe shortages and the lure of high pay.

2. The practice of admitting young men 17 or 18 years of age to a specialized and demanding professional curriculum raises a fundamental question concerning the identification and stability of interest at that stage of maturity. The recent experience of a large state institution with a highly selected freshman class provides a striking example of unstable interests. There, 20% of the entering freshmen left the engineering school before the end of the first semester but four-fifths of them transferred to other curricula of the university. Many of these students had selected engineering because of their desire to attend the university in question and its reputation for engineering, or because of family influence. Their most usual reason for leaving engineering even at this early stage was poor grades, but over half decided they did not like engineering or preferred another field.

At later stages in their college careers, particularly in the universities, some students with outstanding qualifications are impressed by the variety of avenues to opportunity and feel confined by the rigid engineering curriculum. In some cases, they are disappointed in the content of the humanities and social science courses and question whether they are receiving a broad education.

3. Young people in later adolescence are likely to face periods of emotional conflict which may seriously impair, for the time being, their academic performance. The engineering curriculum, in particular, demands such continuous application that it is often impossible to recover from interruptions of this kind.

In most institutions, the increased pace and severity of requirements begin im-

TABLE II

CAUSES OF STUDENT LOSSES FROM ENGINEERING SCHOOLS
(OPINIONS OF 92 DEANS—MAY, 1958)

Losses in Freshman Year	Greatest Importance	Next Greatest	Total Mention
(a) Students' lack of effective work habits	30	26	72
(b) Students' lack of adequate motivation	23	20	71
(c) Lack of effective predictive devices	5	12	43
(d) Inability to adjust to college	2	13	50
(e) Legal requirements for admission	4	0	16
(f) Poor preparation (write-in)	5	2	18
Later Losses			
(a) Lack of genuine interest in engineering	35	24	74
(b) Lack of ability for advanced subjects	33	21	70
(c) Financial	8	17	61
(d) Health, instability, family	3	15	51

mediately in freshman year without what some educators feel is the needed break-in period. Freshman physics in particular is often used as a means of "separating the men from the boys" or has been characterized as a "snow job" which kills motivation. Not infrequently, it results in failure by some students who, after repeating the course, do well in their later work and even in graduate school.

III. Current Trends

The foregoing data on graduation rates were taken from studies which followed individual students over a four-year period and an attempt to approximate the rates obtained by such a study by eliminating numbers of degrees to transfers and part-time students.

Another method of analyzing the current situation on a gross basis, which includes the effect of transfers from junior colleges and other curricula and the number of degrees given to part-time students, is to compare the regular enrollment of each class in two successive years, for example, of this year's sophomores with last year's freshmen.

Table III gives the results of such an approach for the years since 1954.

The progressive decline in these ratios from 1955 to 1958 and the magnitude of its effect on the cumulative ratio seem distinctly serious. The lower recent ratios already have reduced the present sophomore, junior, and senior classes below expected levels. Unless there is a much greater improvement in retention rates than the modest one shown for 1959, future numbers of graduates will be affected severely. Although the decline from 1957 to 1958 may well have been due to factors responsible for the decrease in freshman enrollment, that of the year before also was quite sharp at least at the freshman-sophomore level. Increased delays in earning degrees beyond the four-year period would affect the senior-degree ratio and a minor influence here has been the small increase in fifth-year enrollments.

The direction and magnitude of this trend up to 1958 seemed to make it important to identify the type of institution primarily involved and the factors responsible. For this purpose, enrollments

TABLE III

PERCENTAGE OF RETENTION WITHIN INDIVIDUAL CLASSES OF E.C.P.D. SCHOOLS IN TWO SUCCESSIVE YEARS[1]

	Actual Ratios				Estimated Cumulative Freshman to B.S. Degrees[2]
	Freshman to Sophomore	Sophomore to Junior	Junior to Senior	Senior to B.S. Degrees	
1954 to 1955	79%	90%	97%	89%	62%
1955 to 1956	79%	90%	97%	84%	58%
1956 to 1957	73%	88%	96%	82%	50%
1957 to 1958	68%	84%	93%	82%	44%
1958 to 1959	70%	84%	93%	85%	47%

[1] Fall enrollment figures of years shown; degree figures for academic years 1954–55 to 1958–59. (Reference—J. C. Lewis, H. H. Armsby, "Engineering Enrollments and Degrees in E.C.P.D.—Accredited Institutions—1958, JOURNAL, Vol. 49, No. 6, 1959 and comparable 1959 data.)

[2] The estimated cumulative figure is an artificial one in the sense that it does not apply to any particular entering class. It shows what would occur to any class which experienced through a four-year period the rates applying to each year shown but does not fully reflect bachelors' degrees earned after the close of that period. The trend in this cumulative ratio does show accurately the relative total effect of the annual rates.

TABLE IV

DECREASES IN FALL ENROLLMENTS BETWEEN FRESHMAN AND SOPHOMORE YEAR 1956 TO 1957 COMPARED WITH 1957 AND 1958

	Number of Institutions	Decrease		% of Freshmen		Added Decrease	
		1956 to 1957	1957 to 1958	1956	1957	Number	% of Fresh.
All E.C.P.D.	151[1]	18,063	21,677	27.2	32.4	3,614	5.2
Special group	51	9,717	13,961	30.7	41.5	4,244	10.8
Public	33	8,632	12,399	31.9	42.8	3,767	10.9
Private	18	1,085	1,562	23.8	33.2	477	9.4

[1] In 1956, 153 in 1958. Adjustment for changes would tend to raise all figures in first 4 columns slightly.

were tabulated for all E.C.P.D. institutions, except a few very small or purely military ones, in such a way that for 1956–57 and 1957–58, the decreases in classes in these successive years could be determined. From this tabulation were selected, by inspection, institutions in which the decreases in the sophomore class of 1958 from the freshman class of 1957 were distinctly greater than the corresponding decrease in 1957 over 1956. Both public and private institutions were included although, largely because of their size, the numbers involved in the public institutions were much greater. Table IV gives the results of these comparisons.

It is immediately apparent that the additional decrease in these selected institutions, even the public ones alone, was greater than for all E.C.P.D. institutions. Although others undoubtedly had greater decreases from 1957 to 1958 than for the previous year, all others combined had smaller decreases in the later year.

Ten of the public institutions had engineering freshman enrollments in 1957 of over 1,000 and all had such enrollments of over 300. Twenty of them were in the middlewest and south, with the others scattered. Although the total increase in freshmen in all E.C.P.D. institutions between 1956 and 1957 was only 660, freshman enrollments in these institutions increased 2,000, or about 12%, in that year, and it seems quite possible that much of this increase represented students without appropriate aptitudes and interest.

The private institutions varied widely in size. Ten of the 18 were in the east. Their 1956 and 1957 freshman enrollments were almost exactly equal.

In order to determine the deans' opinions concerning the reasons for increased attrition at this point in these institutions, the returns secured by the Engineering Manpower Commission in response to its January 1959 survey of freshman enrollment trends were examined. One question concerning attrition had been included in this survey and it was assumed that reasons given for it generally would usually apply to the freshman-sophomore losses. Ten of this group of institutions, however, had not replied to the E.M.C. questionnaire and these represented 24% of the total additional decrease in the later year covered. Nineteen others, representing 28% of that decrease, had replied but stated that no increased attrition had occurred. In most of these cases, the additional losses had been largely confined to the freshman-sophomore sequence but in some, the enrollment figures indicated that other classes had been affected.

Of the 22 institutions in the group stating that increased attrition had occurred, six, all publicly supported, ascribed it primarily to "application of higher scholastic standards"; seven to concern about "rigors of an engineering curriculum," four to reports of "diminishing employment opportunities in engineering," and four to various other causes. Of the additional decreases in enrollment occurring in these 22 institutions, about ⅓ each occurred in the institutions giving

TABLE V

DESIRABLE MEASURES TO REDUCE STUDENT LOSSES

	Greatest Importance	Next Greatest	Total Mention
(a) Better admissions procedure	32	13	60
(b) Better counselling and personnel services	18	28	58
(c) More understanding and stimulating teaching	19	17	56
(d) More adequate high school counselling[1]	—	—	9
(e) Increased financial aid	—	—	9

[1] The first three items were listed on the questionnaire. The last two were write-ins.

the first two of these reasons, about ⅙ each in those in the last two categories.

About 30 additional institutions reported to the E.M.C. that they had experienced increased attrition in the past year. Enrollment data were not examined for the 12 non-accredited institutions in this group. Such data, for the E.C.P.D. institutions included, indicated that their increased attrition was quite moderate. On the basis of all affirmative replies to this question, the E.M.C. reported "concern about rigors of an engineering curriculum," "increased interest in other scientific fields," and "reports of diminishing employment opportunities in engineering," in that order, as the predominant reasons given for increased attrition. In public institutions, however, "application of higher scholastic standards" ranked as most important. Although "decreased ability to finance an engineering education" ranked below the other reasons in the E.M.C. tabulation, it was listed as important by a substantial number of the deans replying.

In the special group of institutions included in Table IV, the 1958 to 1959 loss between freshman and sophomore year decreased from the 1957-58 rate of 41.5% to 38%. In the private institutions in this group, this rate dropped from 33% to 26%; in those publicly supported from 43% to 40%. These rates still are appreciably higher than the 1956–57 comparable rates for the same institutions.

For the sophomore-junior sequence, the additional decrease in 1957 to 1958 as compared with 1956 and 1957 totaled 1,657 for all E.C.P.D. institutions. About one-half of this occurred in 5 institutions, 4 public and 1 private, in which the junior enrollment in 1957 was greater than or at least equal to the sophomore enrollment of 1956 due to the number of transfers from junior colleges or other curricula. In 1958 the increase was either sharply reduced or an appreciable decrease was shown. Apparently, therefore, reductions in the numbers of new entrants to engineering at the junior rather than freshman level substantially affected the latest retention ratio at this stage. It may be concluded that the same factors which caused the decrease in freshman enrollments were responsible, at least in part, for this decline. Since the fall of 1958, these same factors apparently have still been influential, since only a nominal increase has occurred in the relative numbers of 1959 juniors and 1958 sophomores.

IV. Suggested Measures for Improvement

The Committee's questionnaire to the deans in May 1958 asked their opinion concerning the relative importance of certain ways to reduce student attrition. Table V presents the results of this inquiry.

Despite the larger number of first-importance votes for better admissions procedure, it seems clear that each of the listed items, as well as others, is considered important.

Measures reported as actually taken include most often efforts to improve counselling and raising of admission standards, with introduction of achievement tests in mathematics and English in

a number of cases. Other measures each mentioned by 2–4 institutions include (a) improved orientation of freshmen, (b) remedial courses in reading and mathematics, (c) freshman tutoring, (d) participation in high school advisement programs, (e) efforts to improve teaching or curriculum. Very few institutions were able to point to tangible evidence of reduced losses. In many cases, the measures undertaken were too new to expect definite results.

As anticipated, it is apparent that only a number of different measures, some of them difficult to make effective, will lead to substantial improvement in this area. Most, if not all, of these measures have been recommended before. In particular, the recent reports of the E.C.P.D.'s Committee on Student Development state very well many of the fundamental approaches needed. The following recommendations of the present Committee merely reinforce the conclusions of others.

1. Where this is not already a matter of routine, each engineering school should examine annually its enrollment figures for individual classes in successive years, adjusted for numbers of transfer students admitted, to determine current trends in retention rates. Periodic follow-up studies of a freshman class through four years will provide more exact but less timely information. Adequate information concerning reasons for student withdrawals is important for interpreting the statistical data.

2. Every means available should be employed to provide high school students, their parents, and teachers and counsellors with a better understanding of the nature, requirements, and rewards of an engineering career and the nature, values, and difficulties of an engineering curriculum. In particular today, there is needed better appreciation of the distinctive contributions of engineering and of science to recent technical developments and of the common and different educational preparation needed for success in careers in those fields.

In this connection, stress should be laid on the importance of high standards of scholastic performance as preparation for full success in further education and later career.

3. Further refinement of admissions procedures is needed with additional emphasis on evidence of achievement as well as of aptitude. In particular, better measures for identifying the important non-intellectual traits requisite for success are badly needed. The College Entrance Examination Board and the Educational Testing Service are now carrying on special projects for this purpose and it is hoped that the results may make substantial contributions to the solution of the problem. Pre-registration orientation periods, including parents as well as students, can reduce ill-advised selection of engineering.

4. Student advisory and personnel services, both through faculty members and centralized offices, should be strengthened. In some institutions, such services are quite complete, but all institutions should seek a way to provide both a friendly counsellor near at hand and more professional assistance when required. Those providing such services should be able to secure information concerning problems which numbers of students are encountering and help to provide the assistance needed to alleviate them. For freshmen, competent student advisers often can effectively supplement staff advisers.

5. There is essential the maintenance of the optimum balance between the preparation of highly competent future engineers and graduation of the maximum number of such engineers from the freshmen admitted. Curricula and teaching methods must be examined constantly from this viewpoint. Losses of students of high calibre are especially serious. Particularly in the freshman year, student loads, course content, and grading practices are of critical importance. Breadth of education should be provided and opportunities for flexibility made available. Of paramount significance is teaching which is not only effective and stimulating but understanding of the student and his problems.

Report of the Conference on Research Goals

SPONSORED BY THE NATIONAL SCIENCE FOUNDATION IN COOPERATION WITH FIFTEEN PROFESSIONAL SOCIETIES

The pace of progress of our whole emerging pattern of scientific and technological development depends largely upon our ability to bring forth research people who can leap ahead to the goals of larger ultimate consequence. However, it is clearly evident that the rigidities of a highly structured society have erected formidable barriers to this kind of originality of thought and independence of effort. Most of our research effort is concerned with small extensions of existing knowledge in well traveled fields. This massive frontal attack is essential to technological and industrial progress. But, by its very nature, most of this research has virtually no promise of leading to discoveries which will open doors to promising new fields of scientific or technological exploration.

Can we now find ways of creating those conditions which will give more of our talented youth a new lease on the future—a new zeal for the pursuit of distant goals that might lead to highly significant discoveries in science and technology? Those who participated in this conference believe that we can. However, this can be achieved only if we are willing to abandon orthodoxies and discard outworn traditions. It can be achieved if we are willing to bring the full force of our institutions to bear upon gaining a much higher degree of liberality of thought, a closer association of youth with the great minds of our times, and an environment which will encourage youth to strike out boldly for the goals of great vision and great promise.

ARTHUR BRONWELL
Conference Chairman

Our nation's scientific and technological progress could be greatly accelerated if conditions more favorable to achieving bold, imaginative pioneering in basic research and in technological innovation could be realized. This was the conclusion of a conference on "Research Goals," sponsored by the National Science Foundation and held in cooperation with fifteen leading scientific and engineering societies in the Olin Hall of Physics at Worcester Polytechnic Institute, December 3–4, 1959. The two-day conference was attended by 51 participants, including college presidents, deans, and directors of research of some of the nation's largest companies.

The vigorous promotion and support of research by the colleges, industry, and government during the past two decades has been, beyond a doubt, one of the most revolutionary and far-reaching innovations in American history. But, with the growth in the size and complexity of research, there have arisen problems of great consequence to our nation's scientific and technological progress which need critical and objective study.

Progress in science and technology has made its greatest strides as a consequence of a relatively few individuals whose originality of thought and brilliance of achievement have blazed new trails leading to discoveries of major consequence. They have been the pace setters who have given new directions to man's efforts, new goals to science and engineering.

But modern research, also requires the amassing of enormous amounts of detailed scientific and technological knowledge. Because of this, it is easy for research people to become preoccupied with goals of relatively small dimensions which, by their very nature, have little promise of leading to significant discovery. In the aggregate much of this knowledge is essential for progress. In the long run, however, progress will be influenced far greater by those exceptional individuals who can cut through the maze of detail and strike out with vigor and originality for goals that might lead to significant breakthroughs.

Today our nation's leadership in science and technology increasingly is be-

ing challenged by foreign competition. There are many who seriously question whether our advance in basic science is commensurate with the needs of our growing technology. Furthermore, it is clearly evident to those who are active on the scientific frontiers that technology has only begun to exploit the possibilities inherent in the basic sciences—that there are limitless possibilities of new technologies growing out of science which are as yet relatively unexplored. Yet new frontiers in both science and technology emerge slowly, despite the enormous increase in research expenditures.

This conference was held in an effort to gain a clearer understanding of influences which guide youth in the selection of their research goals and to explore what can be done to encourage a more venturesome pioneering research spirit which will reach out for goals of larger ultimate consequence.

The specific question posed was: "How can young research scientists and engineers be brought more stimulatively, imaginatively, and creatively into contact with the frontiers of science and technology in such a way as to accelerate significant discovery, both in the advancement of science and in the translation of science into new technology?"

Basic Issues

First, there are many forces acting upon the young researcher which cause him to veer in the direction of conservatism. They begin in education and continue on through the doctorate theses; they are inherent in the way in which research is structured and supported; they appear in the lack of mobility of the scientific and engineering societies. Beyond all of these, there are also the strongly deterrent forces of our social and cultural environment which discourage distinctive effort and originality of thought. These influences tend to cause young research scientists and engineers to undertake research work aimed at small steps in the extensions of knowledge and to discourage the long leaps so essential to the development of a high degree of creative originality. While the dogged persistence of this kind of research is making progress, much more rapid and efficient progress might reasonably be expected if there were greater encouragement for more of our young people to reach for the distant goals.

Second, our colleges and universities seriously need to take a larger view of scholarly research. An entrenched academic conservatism has developed which causes most of our talented graduate students and young faculty members to select research projects which seek to piece out small voids of knowledge, rather than to lead out boldly into new adventures which might have promise of significant discovery. This "hole plugging" research has value in that it contributes to the totality of knowledge, but individually much of it is destined to be of small ultimate consequence. To be sure, occasionally that which starts out to be seemingly inconsequential sometimes develops into discovery of great moment. But this invariably is achieved by those exceptional individuals who have the inquisitive mind and the competence and persistence to drive it through to its larger consequences.

Research effort tends to cluster around certain localized areas which become well populated and self-perpetuating. In each of these areas there develops a community of interest which provides a strong attraction to the young researcher. In the meetings of the scientific and engineering societies he finds a prolific number of papers and publications devoted to these clustered areas and in this he finds vindication for his choice. In the early stages, such clusters are rich in opportunities for discovery and innovation. This is heightened by the inter-action and mutual stimulation of fertile minds in a rapidly developing field. However, such clusters tend to outrun their promise in that the possibilities for major innovation diminish, but they have created large skeletal frameworks which need to be filled in to make the structures technologically useful and thus they continue to attract large followings. The supporting structures of technological research are essential to reduce new technologies to commercial application and they certainly are not to be deprecated. But, if

we are to achieve a high rate of generation of new ideas, it is imperative that our colleges and universities encourage more of the bold venturing forth into untried areas outside of the popularized clusters.

Third, in our college educational programs the student seldom gets any appreciable depth of creative experience, yet this is the very essence of the creative process. The bodies of knowledge have grown so large that our educational processes have tended to become largely factual and analytical, rather than creative. Consequently, the student gains very little experience in taking hold of new and novel situations of a scope which tax his resourcefulness and ingenuity. The student should be challenged with creative experiences throughout his entire educational program. He should be brought creatively and imaginatively into contact with the frontiers of knowledge so that he will gain an appreciation for the dynamic qualities of knowledge.

Fourth, young research people, after they get started in a line of research, are prone to follow this wherever it will lead them, without examining their purpose in a larger context. The truly creative person develops a certain adroitness in continuously reassessing alternatives and goals so that he travels an expeditious path to ultimate accomplishment. This ability to assess directions and goals intelligently is an individual trait, but it can often be enhanced by association with creatively-minded people. It is an essential but often neglected part of education.

Fifth, there is need for developing much more effective means for the communication of ideas. A great teacher can have a profound influence in passing on to young people philosophical ideas and inspiration which will start some of them on the road to great adventure. Generally speaking, this association of fertile, imaginative minds has been the genesis of much of our progress in the evolution of ideas. But, except for the teacher-student relationship, we have not found very effective means whereby leading thinkers of our times can project ideas, inspiration, and methodology to youth. We need seriously to explore more effective ways of bringing talented youth into stimulative personal association with great leaders of our times.

The scientific and engineering societies have not often indulged in philosophical explorations of the future. An individual can report on completed research. But if he attempts to project ahead speculatively, even though he be a leading authority, he may find himself regarded as a charlatan. Yet this philosophical assessment of the future may be the very experience that would captivate the minds of eager, talented young researchers and trigger some of them off in the bold pursuit of new ideas.

The scientific societies have inclined to more of these philosophical programs than the engineering societies. Invariably these have been well attended, highly provocative, and stimulative of widespread discussion. They lift the sights to higher levels of conceptual thought. It is believed that more of such programs, particularly in the engineering societies, calling upon leading thinkers of the times to project their ideas ahead, could be highly instrumental in getting young research people started on the road to more promising and original goals.

Sixth, the engineering societies need to give serious consideration to enlarging their scope of responsibilities so as to penetrate deeper into the sciences. Engineering more and more is becoming interdisciplinary. Increasingly, the various branches of engineering are drawing upon science as well as other advanced technologies for their innovations. The engineering societies have largely confined their attention to areas dealing with those scientific and technological principles which have "proven" utility value. This policy can be short-sighted. Today it should be clear beyond all doubt that there are enormous possibilities outside of the "proven" areas and that these will profoundly influence technology of the future. The slow diffusion of science into engineering and the difficulties of achieving effective cross-fertilization between different disciplines are reasons

why new centers of research are slow to emerge. In certain cases where clear-cut military gains have been recognized, government financing on focussed objectives employing new applications of scientific principles has achieved truly phenomenal results. Radar, atomic energy, and servomechanisms are illustrations of what can be done.

The reaching out into unproven areas of basic science, of course, must start with individual volition and effort. A professional society cannot initiate a new field of research. But it is believed that the engineering societies, by providing a much more encouraging environment for papers, discussions, and publications beyond the proven areas, could go a long way in developing a vigorous, enthusiastic avant gard of research people who are reaching into the unknown. This will call for far more effective working relationships between scientists and engineers than have been achieved in the past.

The fact that numerous splinter societies have been formed in recent decades should be clear evidence that this is a severe and growing problem. Today, a few of the splinter societies are as large as the parent societies from which they emerged. As was pointed out, each splinter society indicates an inadequacy in existing societies to fulfill a dire need—a need which has existed for years until enough pressure has built up to create the new society. The influence of engineering societies in pioneering a new field can be great. But it is not enough merely to adjust long after the pioneering work has been done. They must develop the kind of forward-looking spirit that gives full force to pioneering effort and expressions in the early stages. Entrenched conservatism can be a powerful obstacle to progress. Every engineering society should have among its members that priceless quality of open and challenging minds exploring the distant goals. Experience again and again has shown that, given encouragement, some of these distant goals can materialize surprisingly fast.

Seventh, the essence of creativity is an environment of freedom, encouragement, and opportunity: freedom of the individual to try out his own ideas; encouragement to reach for the distant goals; and opportunity to gain that matchless inspiration and stimulation that comes from personal association with great leaders in thought and accomplishment.

In our structured research programs, that is, in the sponsored research projects in the colleges and universities and in the directed research efforts of industrial and governmental laboratories, freedom is so often bounded by the objectives of the immediate program. In such an environment, the individual usually resigns himself to the directed program, rather than develop ideas of his own. Furthermore, the long leap may require years of painstaking effort and even then it is more likely to fail than succeed. If it does succeed, it may not fit any of the objectives of a structured organization. If the project needs financial support, it is likely to be regarded as too far-fetched to be economically justifiable. All of these deterrents may perhaps be summarized in the statement that freedom and opportunity of a kind that will encourage the high-risk research effort usually run contrary to the objectives of organized and directed research programs, hence they are sacrificed on the altar of expediency.

Eighth, Parkinson's law is an effective deterrent to originality in research. With the growth in size and number of staff, there comes a multiplication of the managerial functions, often falling upon the shoulders of the more able research people. This administrative burden deadens the research sensibilities of those who could be most productive. The top management of research must be vested in highly competent scientists and engineers. There should be no compromising of this issue. But the organization should be staffed in such a way as to handle the administrative work efficiently without excessively burdening the management.

The following are specific recommendations prepared by a Resolutions Committee of the Conference, addressed to the colleges and universities and to the scientific and engineering societies.

Recommendations to Colleges and Universities

1. Develop educational programs which require the student to exercise a high degree of originality and independence of thought. Challenging problems of appropriate complexity which require the student to call upon his knowledge of scientific and engineering fundamentals and in which he must choose among many possible alternatives can be highly effective in giving the student creative experience. However, this should be developed as an integral part of the undergraduate and graduate educational programs. This kind of mental facility cannot effectively be acquired in a single course.

Educational programs which are too strongly departmentalized do not give the student the larger perspectives which are essential for a wide range of imaginative thought and a greater probability of creative success. A number of participants commented that the individual who has a diversity of educational background, with adequate depth, often is the most creative.

2. Invite leading scientists and engineers to meet with students. The infusion of ideas and inspiration by personal association with leading thinkers of our times in seminars and other ways can greatly enlarge the student's horizons. This association should be as personal as possible and preferably over a reasonably extended period, rather than short and cursory.

3. Doctoral research should encourage more venturesome attitudes. The generally accepted requirement that a doctorate student must complete a specified research goal causes students to retrench into "hole plugging" research. It is probable that more graduate students would reach out for the more distant goals where the possibilities of significant discoveries might be greater if they were given more encouragement. A graduate student who undertakes such a long-range project and who exercises a high degree of originality, with persistence and application of effort, should not be penalized by failure to complete the distant objective. Rather, he should be judged on having achieved a reasonable measure of accomplishment even if he doesn't get the ultimate answers.

4. Develop institutional policies which provide an encouraging environment for venturesome research. This starts with faculty members who themselves are highly creative and who can impart to students inspiration for the pursuit of knowledge. An intellectual and scholarly environment in which faculty and graduate students are contributing to the advancement of knowledge provides the most fertile ground for the germination of ideas. Research should be self-inspired by the faculty or graduate student. There should be generous encouragement and financial support for the high-risk projects. Generally speaking, college and university research should be of such a nature as to contribute significantly to the educational function of the institution.

5. Develop closer liaison between college, industrial, and governmental research organizations. Faculty members and graduate students can benefit greatly by association with leading research scientists in industrial or governmental organizations, either in summer employment or in more extended employment opportunities. Likewise scientists in industry could benefit by returning to college for studying under some of the leading educators.

6. Encourage undergraduate and graduate students who have novel, creative ideas to pursue the development of these ideas and help them to obtain financial support. Research apprenticeships whereby undergraduate students work on college research projects often provide valuable creative experience.

Recommendations to Scientific and Engineering Societies

1. Establish more effective practices which will increase the attendance and participation of talented, young members at meetings of scientific and engineering societies. Develop programs which will bring these young people into stimulative personal association with leading scientists and engineers.

2. Encourage the presentation and publication of papers of a philosophical nature which look to the future of science and technology. Invited speakers, who are pioneers in research thought, could do much to lift the visions and ambitions of talented young people to more promising research goals.

3. Develop comprehensive programs for digesting the "state of the art." Young people are confused by the disorganized state of research knowledge. A comprehensive study, now completed as a project of the National Science Foundation, which outlines the state of the art and future research possibilities in the various fields of astronomy is the sort of compilation which could be exceedingly helpful in many fields.

4. Establish society meetings for the purpose of developing a more effective interchange of ideas between scientists and engineers in research areas of broad mutual interest. This cross-fertilization of ideas among scientists and engineers is becoming increasingly important and is not nearly as effective as it should be.

5. Establish free forums at engineering society conventions where any member can make a short presentation of his ceative work, allowing the widest latitude of subject matter, with no publication requirement, except in abstract form. These presentations should be handled without critical review by society committees, which occasionally emasculate original work. Such sessions are regular practice in some scientific societies but as yet have not been adopted by the engineering societies. They provide rapid interchange of experiences and a highly effective means of bringing current research to the attention of the society membership without cluttering up the publications.

6. Actively promote and encourage financial support for research. Consider the possibility of the Society itself sponsoring research using funds contributed by industry. Some trade associations have been highly effective in this kind of operation.

7. Recognizing that creativity begins in the individual at an early age, foster among the Society members a recognition of the contribution which they can make individually by stimulating the creative development of youth. This can be accomplished by undertaking youth projects in their own homes, by youth programs developed in their business establishments, or by other means which will encourage young people to develop ideas and which will give them the means of implementation.

Support for Research in Colleges and Universities

Our nation's colleges and universities can be our most powerful instruments for progress. But they can perform their essential function only if they have financial support adequate to sustain a high level of research activity. Basic research is an essential and indispensable part of the education of scientists and engineers. It serves two purposes. It provides a fountain-source of fundamental knowledge, opening up the frontiers to new technologies and new industries. It serves an even more vital function in creating an educational environment which is sensitive and alert to the newer developments in science and technology. By this process it trains young scientists and engineers to have the capabilities of leading out vigorously and effectively in bringing about technological growth. The educational values of research in the colleges cannot be underestimated; they are vital, imperative, and essential to the bringing forth of creative minds. The rapidly growing graduate programs in colleges and universities throughout the nation will inevitably necessitate a rising level of financial support for research. Furthermore, the precision instruments and equipment needed for research today often involve large expenditures. Excessive diversion of basic research funds to non-educational laboratories at the expense of providing adequate research funds for the colleges and universities could destroy the creative vitality of our colleges and universities.

Conclusions

It should be clearly understood that the foregoing recommendations, to be effective, may necessitate undertaking in

the professional societies programs which are quite different from the customary society operations. They may require fresh approaches in developing meetings, publications, and other professional activities of a more speculative nature which reach out beyond the conventional boundaries of a society's operation and which may run counter to the grain of tradition. In the colleges and universities it will necessitate larger visions and goals on the part of the faculty and graduate students. Industry and government likewise are faced with problems of optimizing their research efforts in terms of an adequate level of scientific and technological innovation.

One's achievements are limited by his area of significant contact. If that area is narrow, and uninspiring, and conventional the accomplishments are correspondingly foreshortened. In research that area must constantly be stretched, not only by enlarging the scope of knowledge, but also by explorations into the future which will capture the imaginations of youth. There must be a stimulating and encouraging environment which will lift the sights and talents of our young people so that more of them will venture forth courageously and with competence to seek out research goals of larger ultimate consequence. Experience has shown that that which is new and exciting today is destined to become commonplace tomorrow. The frontiers will shift to something entirely new, not just an outgrowth of the old, but something which could scarcely have been anticipated.

One final recommendation. Large-scale research is a relatively new endeavor on the national scene. In many ways it still is in its infancy. Our nation's research effort is faced with problems of large magnitude which need critical and objective study. This conference has dealt with but one facet of such problems. There are many others which will profoundly influence our scientific and technological growth. It is urged, therefore, that the scientific and engineering societies take the initiative in bringing together leaders in education, industry, and government to study these problems. It is imperative that such studies be approached not in the framework of preconceived ideas and the preservation of tradition, but rather with a fresh, new and objective outlook. Our ability to cope effectively with these and many other problems in such a way as to bring forth a vigorous and venturesome pioneering research spirit among our young people will largely determine the pace of progress of our emerging pattern of scientific and technological development.

Respectfully submitted,

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Cooperating Societies

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American Chemical Society
American Institute of Chemical Engineers
American Institute of Electrical Engineers
American Institute of Mining, Metallurgical and Petroleum Engineers
American Mathematical Society
American Nuclear Society
American Physical Society
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Institute of Aeronautical Sciences, Incorporated
Institute of Radio Engineers
Society for Industrial and Applied Mathematics

Effect of High School Solid Geometry and Mechanical Drawing on College Grades in Descriptive Geometry

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From time to time questions are raised about the effect of a certain type of training in high school upon performance in college. It often appears to be true that students who have had training in a particular area in high school tend to do better in some of their college subjects. This study deals specifically with the effect of high school training in solid geometry or mechanical drawing upon college grades in descriptive geometry.

The Effect of a Course in Solid Geometry on Grades in Descriptive Geometry

The advisors in the engineering college have frequently commented on the fact that students who have taken solid geometry in high school seem to earn better grades in descriptive geometry (formerly known as Drafting 3) than do those who have not taken solid geometry. To examine this relationship more closely, a control study was undertaken. Since those students who took mechanical drawing in high school might do better in descriptive geometry than those not taking mechanical drawing, it was decided to include in this study only those students who had taken this subject in high school. The type of high school attended (science vs. academic) has been found to be an important factor in determining the type of work a student will do in the School of Technology.[1] Consequently equal numbers of science (SHSG) and academic (AHSG) high school graduates were included in the study. The two groups of graduates were matched on the basis of the Test Battery (using the scores on the several tests that go into the Composite,[2] but not using the high school average). Seventy-one students were included in each group. Among the SHSG, 27 took geometry in high school and 44 did not. Among the AHSG, 31 took solid geometry and 40 did not. The extent of the matching can be judged from Table 1, where the means and standard devia-

[1] Long, Louis and Perry, James D. Mortality Study of College Students. *School and Society*, LXXVII (1953), 103–105.

[2] Tests included in Composite: Scientific Verbal Ability (weight of one), Comprehension of Scientific Materials (weight of two), and General Mathematical Ability (weight of two), Louis Long and James D. Perry. "Academic Achievement in Engineering Related to Selection Procedures and Interests," *Journal of Applied Psychology*, Vol. XXXVII (1953), pp. 468–471. These three tests are part of the Inventory of Scholastic Ability, developed by Kenneth W. Vaughan, and are similar to those included in the original Pre-Engineering Inventory (3).

TABLE 1

COMPARISON OF HIGH SCHOOL AVERAGES AND ENTRANCE EXAMINATION DATA OF GRADUATES FROM SCIENCE AND ACADEMIC HIGH SCHOOLS

Variables		Science High School Graduates (N = 71)	Academic High School Graduates (N = 71)
Test Battery	Mean	82.32	82.46
	SD	3.79	3.76
H. S. Average	Mean	81.27	82.94
	SD	4.27	4.51
Q-score of ACE	Mean	47.59	46.28
	SD	6.79	7.98
Total ACE score	Mean	114.94	113.63
	SD	16.02	17.62

TABLE 2

COMPARISON OF HIGH SCHOOL AVERAGE AND PERFORMANCE ON THE ENTRANCE EXAMINATIONS FOR STUDENTS WHO TOOK SOLID GEOMETRY IN HIGH SCHOOL WITH THOSE WHO DID NOT TAKE SOLID GEOMETRY

Variables		Science High School Graduates		Academic High School Graduates	
		Took Solid Geometry (N = 27)	No Solid Geometry (N = 44)	Took Solid Geometry (N = 31)	No Solid Geometry (N = 40)
Test Battery	Mean	82.30	82.34	83.00	82.05
	SD	3.90	3.73	2.77	4.33
H. S. Average	Mean	80.81	81.57	83.03	82.88
	SD	4.41	4.08	4.28	4.67
Q-score of ACE	Mean	48.26	47.43	46.68	45.70
	SD	6.76	6.72	6.90	8.69
Total ACE score	Mean	114.81	115.41	112.42	114.15
	SD	12.94	16.93	17.65	17.77

tions for the high school average, the Q-score of the ACE Psychological Examination (ACE), and the total score on the ACE are presented. Although these last three measures were not used in matching the groups, the difference between the means of the two groups on all three variables is not statistically significant; this is additional evidence to show the closeness of the matching of the two groups. Table 2 presents data on the high school averages and the performance on some phases of the entrance examination for those students taking solid geometry and for those not taking it. None of the differences between the means of these two groups for the variables presented in Table 2 is statistically significant.

The mean grades in Drafting 3 for students who took solid geometry in high school and for those who did not take solid geometry are presented in Table 3. The mean grades in drafting are higher for those who took solid geometry than for those who did not take it, regardless of whether the student graduated from a science or an academic high school, but the extent of this superiority is not great enough to be considered statistically significant.

An analysis was also made of the effect of having taken solid geometry in high school on a test measuring Spatial

TABLE 3

COMPARISON OF GRADES IN DRAFTING FOR STUDENTS WHO TOOK SOLID GEOMETRY IN HIGH SCHOOL AND THOSE WHO DID NOT TAKE SOLID GEOMETRY

	N	Drafting Grades	
		Mean	SD
Science high school graduates:			
(a) Took solid geometry	27	75.74	12.45
(b) Did not take solid geometry	44	71.14	11.32
Academic high school graduates:			
(a) Took solid geometry	30	75.00	10.95
(b) Did not take solid geometry	40	71.75	12.90

TABLE 4

COMPARISON OF GRADES IN DRAFTING 3 AND 4 FOR STUDENTS WHO DID, WITH THOSE WHO DID NOT TAKE MECHANICAL DRAWING IN HIGH SCHOOL

	Grades in Drafting				r Between Grades in Drafting 3 and 4
	Drafting 3		Drafting 3		
	Mean	SD	Mean	SD	
Took mech. drawing (N = 157)	79.6	10.4	77.2	11.7	.54
No mech. drawing (N = 152)	78.2	10.5	75.9	12.5	.49

Visualizing Abilities [3] given as part of the Entrance Examination. Science high school graduates with no solid geometry did slightly better on the two parts of the test than did those who took solid geometry, whereas the reverse is true for academic high school graduates. However, none of these differences was great enough to be considered statistically significant.

The Effect of Mechanical Drawing in High School on Grades in Descriptive Geometry

The grades earned by students in the first year course in drafting (formerly Drafting 3 and 4) during several terms (spring 1952, fall 1952, and spring 1953) were analysed to see whether those who took mechanical drawing in high school made better grades in drafting than did those who did not take mechanical drawing. The average grades in Drafting 3 and 4 for 157 students taking mechanical drawing are presented in Table 4 along with the grades for 152 students who did not take mechanical drawing. The difference between the means for the two groups is not statistically significant for either of the two college drafting courses. Training in mechanical drawing does not appear to increase the likelihood of the student making better grades in a college drafting course dealing with descriptive geometry. The correlation between the grades in the drafting courses is also given in Table 4.

It also semed desirable to investigate the effect of training in mechanical draw-

[3] Test was constructed for City College by Kenneth W. Vaughan and is similar to a test included in Pre-Engineering Inventory, W. Kenneth Vaughan. "The Pre-Engineering Inventory." JOURNAL, XXXIV (1944), 615-625. The test consists of 24 orthographic projection items and 32 items involving rotation of cubes.

TABLE 5

COMPARISON OF PERFORMANCE ON TESTS OF STUDENTS WHO DID, WITH THOSE WHO DID NOT TAKE MECHANICAL DRAWING IN HIGH SCHOOL

	Took Mech. Drawing (N = 157)		No Mech. Drawing (N = 152)		P Value
	Mean	SD	Mean	SD	
Spatial Visualizing Ability					
Part 1	15.10	5.49	9.86	6.38	.01
Part 2	13.18	6.79	11.57	6.29	.05
Both parts	28.28	10.53	21.39	11.06	.01
General Math Ability	42.08	12.42	36.99	12.11	.01
Q-score of ACE	48.15	7.64	48.01	8.21	>.05
Composite	168.71	7.15	167.71	6.69	>.05

TABLE 6

RELATIONSHIP BETWEEN ENTRANCE TEST SCORES AND COLLEGE GRADES IN DRAFTING

	Correlation with College Grades					
	Took Mech. Drawing (N = 157)			No Mech. Drawing (N = 152)		
	Drafting		Both Courses	Drafting		Both Courses
	3	4		3	4	
Spatial Visualizing Ability						
Part 1	.38	.34	.42	.45	.47	.54
Part 2	.27	.24	.29	.31	.32	.37
Both parts	.39	.33	.41	.44	.45	.49
General Math Ability	.42	.36	.45	.40	.30	.40
Composite	.45	.40	.48	.40	.29	.39

ing on some of the tests included in the Entrance Examinations. Data in Table 5 indicate that students who have taken mechanical drawing do better on the tests measuring spatial visualizing and mathematical abilities than do those who have not taken mechanical drawing. However, the difference between the two groups is not statistically significant when their Entrance Composites [4] are compared. The correlations between the scores on the tests and grades in drafting are reported in Table 6. It would appear that the Composite and the scores on the tests measuring spatial visualizing and mathematical abilities predict drafting grades to about the same extent. It is interesting to note that the correlations reported in Table 6 are not much lower than those in Table 4 where grades in drafting are intercorrelated. At the same time, a drafting grade is better than data based on the entrance examinations in predicting succeeding grades in drafting.

[4] High school average and test battery being given equal weight.

Summary

The effect of having taken a course in high school in solid geometry or mechanical drawing upon college grades in a course in descriptive geometry was investigated. The effect of these high school courses on a test measuring spatial visualizing abilities was also studied. It was found that students taking these high school subjects do not earn grades in descriptive geometry that are significantly higher than those who have not taken such subjects in high school. Performance on a spatial visualizing test is not significantly affected by a high school course in solid geometry, but those students who have had mechanical drawing in high school do make scores on this test that are significantly higher than those who have not had mechanical drawing.

Special in June: COMPUTERS IN ENGINEERING EDUCATION

Coordination of Mathematics and Physics

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The basic concepts of engineering education have undergone drastic revision during the past decade. Essentially, these revisions have produced new curriculums heavily based on mathematics and physical science. The really fundamental character of the new concept, however, is that the student is to be educated for an understanding of basic ideas of the physical world and of the underlying principles which constitute man's understanding of that world, along with both skill and understanding in mathematics. One can contrast this with the more traditional approach which called for the training of students to do specific tasks. As might be expected, there are many different ideas regarding techniques of instruction, content of courses and structure of curriculum. For example, there is no unanimity regarding the part which physics should play in the engineering curriculum. How and by whom should it be taught? What should be its content? Where should it appear in the curriculum and what contribution is expected from it? These questions have been raised and answered by persons at all levels of the engineering faculty, but unfortunately the answers have been by no means consistent. One group which we might describe as the left-wing would have physics *per se* dropped altogether and only certain "desirable" pieces picked up and considered in engineering courses. This group has indicated that such a procedure would permit the saving of much time and also make possible the presentation of engineering as a unified, basic body of knowledge. Another, perhaps equally radical group, believes that engineering is primarily the application of physics and that consequently, a good curriculum is merely a suitable collection of physics courses. Most educators are inclined to believe that the right picture lies someplace between these two widely separated views. In any case, there is general belief that physics courses require great modification, if they are to become and remain acceptable parts of engineering curriculums.

By and large, this unhappy situation is the fault of the physicist himself. He has persisted, for many academic generations, in presenting an engineering physics course which was a somewhat intensified repetition of a good high school program. Although calculus is referred to freely in the preface of almost every physics text, its use has been so sporadic that courses have remained pretty much a collection of formulas. Thus, college physics has been an island in the curriculum. It has failed to take advantage of those pieces of information which high school physics had to offer, and at the same time, it has failed to constitute a body of knowledge which could be used as a starting point for other courses. Failure rates have been high and achievement has been low. One could seriously question whether physics, as it has been taught, made a really significant contribution to the engineering curriculum. This statement is a criticism of the traditional physics course. It does not mean that physics should be abandoned in agreement with the philosophy of the left-wingers. But, it does mean that engineering physics must be modified radically.

If the physics course is to provide a

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background for engineering, then it must provide an understanding of basic concepts and principles. Furthermore, these concepts and principles cannot be limited to those of the classical era. Formulas must be sacrificed in favor of a fundamental approach through the use of mathematical tools. Calculus must be among those tools, unless coverage is to be seriously limited. Since engineering educators are an impatient lot, one finds both beginning calculus and beginning physics taught in the same semester of the curriculum. Thus, some scheme of coordinating the two is necessary. The educators at the Pratt Institute are as impatient as any others, but nevertheless, they feel that physics is a necessary part of the engineering curriculum. This paper presents one of many possible modifications of the physics course, along with a scheme for coordinating it and the calculus which is presented simultaneously. The procedure which will be outlined has produced gratifying results at the Pratt Institute.

Objectives of the New Approach

In general, the new approach is designed to emphasize basic concepts and principles and to promote understanding. Specific objectives include skill in the application of fundamental principles to the solution of problems, and skill in the use of vector analysis and calculus for the description of physical situations. Particularly important is an attempt to avoid repetition of high school work, and to make the course a solid structure upon which advanced work can be based, and for which no duplication is necessary.

Mathematics and Physics Together

Although mathematics and physics are coordinated in the program which we shall discuss, the two nevertheless are taught as separate courses and by different persons. Since the physicist desires to make maximum use of both calculus and vector analysis, two problems in coordination arise. One of these, however, tends to aid the solution of the other. To give the mathematics department time to develop the beginnings of calculus, a lag must be introduced into physics. This is done by devoting the first nine periods of physics to a study of vector algebra. The vector concept is defined in a manner acceptable to the mathematician although based upon physical notions. The dot and cross product are defined and interpreted as well as the product of a scalar and a vector. Once the basic concepts are laid down, then vectors are considered with reference to Cartesian coordinates and their associated unit vectors. Finally, the position vector is introduced and applied to problems which are largely geometric. While this is going on, the mathematics classes meet fifteen times, during which the notion of limit is introduced and ultimately the derivative is defined. Simultaneously, integration is taken up and applications of both differentiation and integration are made to algebraic polynomials.

At this point, the physics course begins a critical but descriptive examination of space, time, mass and force. This leads to the statement of Newton's three laws of mechanics, with emphasis upon the concept of inertial space. Vector analysis and calculus constitute the mathematical tools required for this purpose. During this time, the mathematics course introduces analytic geometry and applies calculus to it. At the same time, differentiation and integration are kept continually before the student in the mathematics course, and they are used on every problem in the physics course. Since the study of statics is postponed until after dynamics, physics is concerned largely with problems of motion. In solving these problems, the student cannot avoid the use of calculus because no formulas are derived and the use of them is not permitted. All problems, no matter how simple or complex, must be solved by the use of Newton's Laws and calculus. At first, constant of integration is found by reference to initial conditions, but ultimately the definite integral notation is introduced in the physics course simply as a means of eliminating the constant of integration. Shortly thereafter, the definite integral is developed in mathematics.

Newton's Law of Gravitation is presented in the physics course shortly after

his Laws of Dynamics have been introduced. Gravitation is discussed rather carefully and its approximation by mg is derived for regions near the surface of the earth.

The physics text material includes a separate chapter on derived concepts. In this chapter, Newton's second law is integrated first with respect to time, in order to introduce the notions of momentum and impulse, and then with respect to distance, in order to introduce work and energy. These four new concepts are said to be derived concepts. Thus, definitions of kinetic and potential energy arise through the application of integration to a basic principle. Gravitational potential energy change is considered for objects both near the surface of the earth and far from the earth. In all these considerations, the vector method in terms of Gibbs' notation is continuously used.

Only one additional upset of the traditional mathematics course is required in the first term. The differentiation and integration of sines and cosines should occur prior to the end of the tenth week. This background is needed in physics for the consideration of angular velocity, rotating coordinates, circular motion and simple harmonic motion.

During the second term of the course, only one modification of the traditional mathematics approach is demanded. Partial differentiation is introduced late in the second term in order that it may be available for early use in the third term of physics. In doing this, one must be careful not to postpone the differentiation and integration of exponentials and logarithms, since they are required for second term work in physics. Although the second semester of physics is primarily a study of fluids and heat, a consideration of circular motion and the motion of variable masses is deliberately postponed to the second term in order that vectors may be kept before the students. Since heat is considered from the point of view of particle motion, mechanics continues to play a predominant role during the second term.

At present, our experience encompasses only the first two terms. However, our results have been so gratifying that we shall have no hestitancy about using a completely vector approach to electricity and magnetism during the third term. We have taken the field equations as our goal for third term physics and expect no difficulty in achieving that objective.

For the reader's convenience, an appendix to this paper contains coordinated course outlines for mathematics and physics during the first two terms.

Mechanics of the Operation

The new physics course and the coordination of mathematics with it involved a significant departure from previous practices. As a consequence, experienced, successful faculty members were considered necessary for the project. Unfortunately, there was not enough equally experienced faculty to man small sections for the entire freshman class. Thus the lecture method was chosen for both physics and mathematics. In physics, there were two lectures per week and one recitation. The recitations were in small sections. There were four lectures and one problem day per week in mathematics. Through this procedure all students received essentially the same instruction. In physics there were seven hours of examination and in mathematics there were ten. Papers were graded by a carefully selected group of advanced students who were given definite grading instructions prior to each examination.

The same treatment was given to all regular freshmen without regard for their relative abilities as indicated by tests.

A Survey of Results

Interest was at a high level in both courses. It increased steadily in physics and although this effect was discernible in mathematics, it was less pronounced. At the end of the first semester, 14.5% of the students had failed physics and 19.3% had failed mathematics. For the second semester, 5% failed physics and 10% failed mathematics. Thus, the survival rate for two semesters of physics was 81% and that for two semesters of mathematics was 73%.

Prior to the beginning of the course we obtained ACE, PEAT, Reading Com-

Week	Mathematics 1st Term	Physics 1st Term
1, 2, 3	Coordinates, functions, limits, derivative, slope rate, anti derivative.	Vector algebra (Gibbs' notation).
4, 5, 6	Polynomials, rational functions, implicit functions, differential, continuity, maximum and minimum.	Space, time, speed, velocity acceleration, mass, force, Newton's Laws, gravitation, friction.
7, 8, 9	Rolle's Theorem, mean value theorem, differentiation of sines and cosines, area as an integral.	Impulse, momentum, work, energy, applications, systems and conservative principles.
10, 11, 12	Definite integral as a limit, areas bounded by curves, volumes of revolution, approximations, arc length, surface of revolution, average values.	Angular velocity and acceleration, rotational motion, rotational energy, mass center, moment of inertia, applications.
13, 14, 15	Moments and mass center, centroid and gravity center, Pappus Theorem, moment of inertia, radius of gyration, parallel axis theorem, static pressure, work by variable force.	Elastic and inelastic deformation. simple harmonic motion, statics.
	2nd Term	2nd Term
1, 2, 3	Discussion of curves, tangents and normals, locus, rotation of axes, conic sections in Cartesian coordinates, introduction to polar coordinates.	Circular motion, impact, variable mass, machines.
4, 5, 6	Polar coordinate equations, differentiation and integration of trigonometric functions, inverse trigonometric functions, logarithmic and exponential functions, simple differential equations, hyperbolic functions.	Fluids at rest, fluids in streamline motion, viscosity surface phenomena.
7, 8, 9	Parametric equations, vectors in 2-space applied to motion and geometry, 3-space rectangular, cylindrical and spherical coordinates, vectors in 3-space.	Temperature, thermal expansion, heat as energy, ideal substance, kinetic theory, gas laws.
10, 11, 12	Solid analytics by use of vectors, space curves and motion, partial derivatives, tangent planes, normal lines.	Internal energy, reversible processes, Carnot cycle, absolute temperature, specific heats and quantum theory.
13, 14, 15	Increment of function of several variables, directional derivatives, gradient and divergence ("del" operator), total differential, max and min, higher order partial derivatives, least squares, exact differentials, introduction of line integral.	Heat in solids and liquids, calorimetry.

prehension and Mechanics of Expression scores on all students. Only the Reading Comprehension score gave significant information regarding the likelihood of failure. For this test, there were three times as many failures in the group below the fiftieth percentile as in that above. This same figure applied to both mathematics and physics. Failures in *both* mathematics and physics were more than ten times as great for the lower half, as for the upper. These values are based upon very small samples.

Our initial experience has been entirely satisfactory. Experimentation will be continued, but primarily for the purpose

of finding the optimum division of time between lecture and recitation. We are also attempting to develop a set of demonstration experiments appropriate to the physics course.

Some Observations

So far as the students were concerned, the physics course was entirely new in concept. In addition it was extremely intensive, possibly the most intense in any school today. And yet, it was presented with outstanding success by a method in which lectures predominated. All regular freshmen took the course.

There are three unproven but seemingly likely implications: (1) let your freshmen learn from your ablest teacher, even if it means using the lecture method; (2) a course which presents concepts and principles and demands understanding, is not beyond engineering freshmen; (3) it is likely that we have underrated student capability in the past.

INDUSTRIAL ENGINEERING SUMMER SCHOOL

Purdue University

June 18–19, 1960

Sponsored by the Industrial Engineering Division

The rapid advancement of the physical and social sciences has resulted in many new developments that should be integrated into the Industrial Engineering Curriculum. This Summer School will provide a forum for the interchange of ideas on the best way in which to integrate new material into the subject matter taught in industrial engineering. The program will consist of the following topics:

Saturday, June 18—

Mathematical Requirements in Industrial Engineering
Statistical Requirements in Industrial Engineering
Psychological Developments of Importance to Industrial Engineering
Physiological Developments of Importance to Industrial Engineering
Sociological Developments of Importance to Industrial Engineering

Sunday, June 19—

Systems Analysis
Systems Simulation
Incorporating Frontier Areas into the Industrial Engineering Curriculum

Arrangements for housing and meals will be similar to those for members attending the Annual Meeting. Registration for the School will be separate from that of the Annual Meeting, and the fee of $3.00 should be mailed to Professor H. T. Amrine, Department of Industrial Engineering, Purdue University, Lafayette, Indiana.

The Mark of an Educated Man

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In an earlier day, when, if we may believe Matthew Arnold, people were looking at life steadily and seeing it whole, Aristotle said, "It is the mark of an educated man to look for precision in each class of things just so far as the nature of the subject admits; it is evidently equally foolish to accept probable reasoning from a mathematician and to demand from a rhetorician scientific proofs."

In an age when men use the authority of "scientists" to decide what brand of cigarettes to smoke, Aristotle's definition of an educated man has small support, even in the academic grove. "Scientism," the misapplication of science and the scientific method, has won the day in more areas than we are perhaps willing to admit.

The advent of Sputnik called forth an unequalled flood of discussion about educational goals, methods, and financial assistance, but all except a few scattered statements dealt with our educational needs in the sciences and engineering subjects. The voice of the humanist is hardly heard in the land, and the singing of the physicist has come.

But if the humanist in the American college has had less to say, it is, to a great extent, his own fault. He has in many cases lost his role of social commentator and aesthetic guide. Lost in grudging admiration of the physical scientist and suffering from envy of the undergraduate popularity of the social sciences, the humanist has more and more emulated, borrowed from, and downright copied the method of his scientific brethren. Forgetting his role as guardian of the testament of the human spirit, he has left more and more of his written and painted treasure to the social scientist, forgetting that it is from the artists and poets, the "unacknowledged legislators of the world," that the social scientists have learned much if not the bulk of their knowledge of man and society. Indeed, we have almost lost even Leonardo from the realm of art to the realm of science and have forgotten that science until very recently was a part of philosophy, and only a part at that.

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Not by Aggression

But the loss in the humanities has not been the result of aggression by the scientists as much as it has been the withdrawal of the humanists from their proper sphere. Seeking to gain a position of new respect and intellectual status in a technological age, teachers of literature have built up in recent decades various critical schools which have all the appearance and trappings of scientific method without its necessary controls or applications. In doing so they have robbed their subject matter of the immediacy of impact which is literature's *raison d'etre*. They have attempted to codify and measure the imponderable, to demand mathematical proofs of the rhetoricians' insights. The result has, at its worst, brought sterility to the teaching of literature and at its best often led to the choice for teaching of literature which has lost its relevancy for the students in the classroom.

This process has been hardened into academic rigidity in many graduate schools, whose products then return to undergraduate teaching to propagate their kind. The English professor spends a

good deal of his time training future graduate school students, forgetting the reason why literature or the arts in general are in the curriculum at all. It is not long before, as in some dramatic schools, the "method" is all. "What school of criticism do you belong to?" takes the place of "What or whom do you like or enjoy?" The end product may be the group of Honors English students, in one university I know of, who unanimously voted that they preferred prose to poetry, while a majority preferred critical writing to fiction. The true consummation was a girl who admitted that she preferred the footnote comments to the text.

There are many humanities teachers in engineering schools who feel exiled in a foreign land, and well they may if the educational process they wish to take part in resembles the one outlined above –even after removing the pejorative remarks. But I would submit that it is in the technical schools that we may get back most quickly to the ideals of the creative artists whose work is our subject matter. First and foremost is that of enjoyment. There is no need to attempt to cloak our work or approach with scientism. No group of scientists or engineers is going to be fooled by us on that score. We will engender far more interest by admitting the comparative indefiniteness of our subject matter. We can show, with little difficulty, that the problems which the great artists raise are at heart insoluble, or at least solvable only on an individual basis. We can show that the value of an individual artist's solution is as a guidepost and aid to the individual student's solution or attempt at solution. We can show that although, through science, the height of the star of every wandering bark may be taken, the worth is still unknown.

Furthermore, rules and methods of analysis can never become primary goals for those to whom literature will always remain, and thankfully so, an avocation rather than become a vocation. Graduate school methods and goals, insofar as they become ends rather than means, must remain meaningless in the engineering and science curriculums.

Literature can be approached as a record of man's achievements and failures, his aspirations and despair. More than that, though, it is a record of individuals, and it fosters individual response in students whose primary intellectual weakness is group consciousness.

The Opportunity

Perhaps the greatest opportunity we face in engineering schools is the chance to show life in its totality, for, in general, we are freed from the departmental restrictions which limit the expression of a single art form to specific courses. The teacher can show the interrelationships of all the arts and thus heighten the interest in all. Shown within their proper historical situations, the arts reveal individual responses to real problems and gain an immediacy of impact that might otherwise be slight. I need hardly point out the danger of treating literature or any of the other arts simply as historical events, of course. This makes them mere documents for the social scientist. At best we should see these expressions *within* historical settings yet offering meaning and inspiration for the student's present experience. If they do not become existential realities for the student, they "are of all things most miserable."

A Course in Western Civilization

At Case Institute of Technology the student is exposed to a wide range of literature, music, art, and philosophy during a two year, four hour a week course in the backgrounds of Western Civilization. Each teacher approaches the material covered in his class section in his own way, emphasizing those points he feels to be most important and those materials he finds most interesting. As the staff is made up of teachers whose own major interests range from history through literature to the fine arts, a wide latitude of treatment is obviously the result. The department feels, however, that a teacher will do his best work and inspire the most active response from his students when left relatively free to express the course material in his own way. Every student has four different teachers

in his two year sequence, however, and gets a wide variety of educational experience.

Under these circumstances what follows must of necessity be a quite personal record of how I as one member of the staff approach the teaching of literature in an interrelated core course in the humanities. I will cite but three examples and hope that they will represent fairly the rest.

By the time we reach Sophocles' *Oedipus Tyrannus*, the student has read all of Homer's *Odyssey* and most of Professor Kitto's *The Greeks*. He has spent a good deal of time on the concept of the *polis* and its influence on Greek thought, indeed its all-encompassing nature. Aristotle's statement that "man is a political animal" has been foreshadowed. The Greek virtue of *arete* and sin of *hubris* have been emphasized. A week has been spent on Greek sculpture and architecture, where the transition from the stylized forms of archaic art through the ideal, proportioned beauty of the Hellenic, to the realistic portrayal of the late Hellenic and Hellenistic periods have been shown. Some comparison has also been made with the similar transition of the Italian Renaissance. The class has already read Aeschylus' *Agamemnon* and seen the chorus in its stylized form and religious context. They have also been given a brief survey of the early development of the Greek theater in a lecture.

A discussion of the play begins with a contrasting of the meanings of tragedy, pathos, and sublimity and ends with the question of whether true tragedy is possible today. I present Aristotle's definition of a tragedy and then let the class work it out in the play with special attention aimed at Oedipus' sin of *hubris*. At first we deal primarily with the characters as recognizable and believable human beings apart from the religious overtones of the play, but the students' questions concerning the prophecies of the oracle lead inevitably into a discussion of Oedipus' free will, or lack of it, the preordination of the gods, and the power of the Fates. Then the role of the chorus comes up and the change from the chorus in Aeschylus is discussed and comparable analogous changes in sculpture are brought out. Attitudes towards the *polis* of the various characters are analyzed and compared with what the students have read in Kitto as well as what they have witnessed as modern attitudes toward the state.

Before returning to the question of tragedy, I lead off, by way of the dialogue:

> Oedipus: But surely I must needs fear my mother's bed?
>
> Jocasta: . . . fear not thou touching wedlock with thy mother. Many men ere now have so fared in dreams also.

into a short digression on why Freud picked the phrase "Oedipus complex" and try to have the class see whether the phrase has meaning in the play or whether Freud has taken merely a surface action and given it another meaning.

As I say, the discussion, taking usually two and a half to three class hours, then ends up on a major problem of modern drama, whether, with our modern feelings of determinism, psychological and cosmic, a playwright can write a true tragedy or must aim, at best, at a deeply-moving, pathetic situation. As all of the students have read *The Death of a Salesman* in their freshman course, a good argument is always forthcoming.

Poetry

Selections from Latin poetry are our first chance to do anything with poetry as such in the course, for the Homer is usually read in prose translation. The question of treating any translation as real poetry is, of course, great, but this in itself leads to a profitable discussion of the values and drawbacks of translation. The major discussion of translation, though, arises during the reading of the New Testament, when I compare the Greek, a literal translation, the King James, and the Revised Standard versions of the opening verses of the gospel of John.

The first Latin poem I treat is a short lyric of Catullus. First I read the poem in Latin and give a short analysis of

Roman metrics. Then we contrast the method of Latin scanning of long and short syllables (with a gratuitous snide aside at bad teachers of scansion in some high schools) and the English use of stressed syllables, using "This is the house that Jack built" as an example of the difference in the syllabic make-up of "equal" feet. To show what part meter plays in poetry, I use the literary debate between Frost and Sandburg concerning the "rules of the game" of poetry. Frost said once that writing poetry without rhyme or meter was like playing tennis with the net down. Sandburg countered that "you can play a better game without the net." Frost answered, "Sure you can play a better game without a net—and without rackets or balls—but it's not tennis."

Catullus is a good example of a poet whose subject matter raises the question of the necessary content of a poem. The question naturally arises in class as to why anyone would use poetic form to begin with. This seems best answered by working out, with examples, the principle that content generally determines form in any art. But then there arises the question as to how "serious" or "important" content must be to be considered a fit subject for art. Here I let them play with Frost's statement that the only thing you need for a poem is a "tenable position."

"On Lesbia's Inconstancy," translated by Theodore Martin, provides a light example of sheer enjoyment with just sufficient irony and sophistication to set the note for other Latin verse and to set the tone for life in the late Republic. Like woman's constancy, it is writ in air or running water and shows that even the lightest verse can catch a universal idea.

The poetry and prose of the twentieth century are, of course, the easiest to approach in class. Many students, of course, react negatively to the poetry of Eliot, and yet it would be ridiculous to leave him out of a course covering twentieth century thought. As the purpose of the course is to interest and attract the student rather than to antagonize him, I have found it far more useful to teach "The Love Song of J. Alfred Prufrock" and "The Hollow Men" than to attempt, in the time at our disposal, to make clear the intricacies of "The Waste Land," "Ash Wednesday," or any of the Quartets.

By the fourth semester the students have a background which makes both of the headnotes of "The Hollow Men" meaningful: Conrad's "Mistah Kurtz—he dead" and "A penny for the Old Guy." But, more important, they have a sense of meaninglessness and emptiness, loneliness and lack of illusions which makes this poem an uncomfortable commentary on their own lives as well as life in the 1920's. And it is this dual quality which we discuss in class. Obviously it helps them understand one facet of life in the 20's, but it also helps them to formulate ideas on the 50's. Eliot could never know, when he wrote the poem, the potential power of his concluding lines: "This is the way the world ends/Not with a bang but a whimper" in a world threatened by the atomic bomb. The astounding thing to me is that even in the obvious presence of the bomb, the students feel the increased truth of Eliot's lines.

Four semesters of a Western Civilization course are certainly not the only way, and, perhaps, not the best way to teach literature, but they are certainly not a bad way. Literature is seen as but one means of human expression, one way of describing and dealing with the *comedie humaine*. It gains, I think, by being seen so clearly in its historical context—if, it must be added, it is also related continuously with the experience of the student, and if it is seen as a source of genuine enjoyment. Then the perspectives of literature become as wide as man's history and as deep as the responses of the human soul.

The Convergence of Engineering and Liberal Arts Education

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There is considerable stir these days for educational reform. At the college level it is particularly vigorous in engineering education. Its intensity may be gaged by the fact that it has already accomplished, unconsciously, a modicum of homogenization between two hitherto immiscible parts of higher education—undergraduate engineering education and liberal arts education. One may not be certain any more that liberal arts education is the monopoly of the liberal arts college, nor can it be assumed that undergraduate engineering education is exclusively the province of the engineering school.

In undergraduate engineering education there is a well defined trend away from vocational training or know-how courses. The emphasis is shifting from the time-honored precept of "training engineers for industry" to the more sophisticated one of education for the balanced intellectual development of an individual via scientific-humanistic studies. At the Massachusetts Institute of Technology proponents of devocationalized or "pure" engineering education argue that it may be equated to a form of science-based liberal education analogous to that required for the law and medicine. Specialized vocational studies in engineering or non-engineering areas, as for law and medicine, are considered proper efforts for the postgraduate years.

The denigration of vocationalism in the undergraduate engineering curriculum is a consequence of the changing industrial structure. In the nineteenth century, and in many cases up to the beginning of World War II, industry was, in the main, developed about a craft-based technology. The engineer was generally considered as an upper class craftsman. His education included forge, foundry, pattern-making, welding, machine shop practice, drafting, and surveying, in addition to such specialized courses as air conditioning, refrigeration, and internal combustion engines, serving the particular needs of particular sectors of industry. Today no sector of industry feels itself immune to the accelerated technological obsolescence created by the swift adaptation of but a small part of the burgeoning scientific knowledge to automated industrial advantage. Modern industry is undergoing a rapid change-over to a science-based technology which is itself continually changing with advances in science. Know-how technique or status quo education in this milieu is likely to become obsolete before a student receives his degree. It is deemed much more important for the engineer to become a colleague of the scientist than the superior of craftsmen. This viewpoint has widespread support among industrial managers. It is being complemented also, with their approval, by efforts to unify engineering knowledge thru more intimate liaisons with the physical sciences and modern mathematics.

The Engineering Sciences

The corpus of the purified and unifying engineering knowledge, exclusive of its foundation of the pure sciences and mathematics, has been canonized by the Engineers' Council for Professional Development as the "engineering sciences." They are modifications and extensions of the pure sciences, principally physics for the analysis of facets of an engineer's problems. They are the basic engineer-

ing courses for the twenty-eight accredited engineering curricula in the United States. In the opinion of the reformers of engineering education it is these courses alone, cutting across the boundaries of conventional engineering curricula, which constitute negotiable knowledge in these times of swift science-based technological advance.

This approach to a unified engineering education is not new. It has informed engineering education at Oxford, Cambridge, and Harvard for the past fifty years.

Despite the pressures for more engineering science, physics, and mathematics, a firm line has been held with respect to the inclusion and importance of social science and humanistic studies in engineering education.

Of greater importance than the present orientation of the new engineering education toward the profession of engineering is its identity as a scientific-humanistic form of education. It is then not so surprising to note the acceptance of engineering science courses for partial fulfillment of the requirements for the bachelor of arts degree by more than one hundred and sixty liberal arts colleges, and the establishment of the engineering sciences as liberal arts departments at such historic defenders of the true liberal arts faith as Harvard and Dartmouth.

At Harvard the engineering sciences are offered by the Division of Engineering and Applied Physics of the Faculty of Arts and Sciences. They lead to the traditional liberal arts degree of bachelor of arts. The purpose of the studies is not simply to serve as the first stage in the preparation of an engineer. It is rather to give a student so firm an intellectual preparation that he may make himself at home in many areas of postgraduate study, including law, medicine, business administration, physics, mathematics, as well as engineering and engineering research. This type of education is consistent with the traditional liberal arts position which holds that it is the function of a college to permit its students to make connection with a wide variety of professional work but not to do it. It is for Harvard a culmination of over a century of effort, starting with its Lawrence Scientific School in 1847, to reconcile a heavily endowed engineering education with liberal arts education.

At Dartmouth College, beginning in 1871, a liberal arts degree was required for entrance into the two-year civil engineering course offered by its associated school, the Thayer School of Civil Engineering. It was not uncommon in earlier days for a graduate of a classical college, well instructed in general mathematics and literature, to secure engineering training at West Point or Rensselaer in a semester or two. After 1893, a student could matriculate to the Thayer School after three years in the liberal arts college. A year, then, of engineering school studies, approximating the engineering sciences, was accepted by Dartmouth College as fulfilling the requirements for its bachelor of arts degree. The fifth year led to the award of an engineering degree by the Thayer School.

This development has been the American prototype of the combined liberal arts-engineering curricula now widely found in the United States; its inspiration was the eminently successful lycee-engineering school sequence established in France by Napoleon I.

In 1958, however, Dartmouth College established a department of engineering science to take its place as a liberal arts department alongside of the earth, physical, social, life, and political sciences, as well as the humanities. Where the old curriculum was stratified into three years of liberal arts, including the mathematics and physical science prerequisites, administered by the liberal arts college, and two years of engineering studies administered by its Thayer School, the new is stratified into a four-year engineering science major under the jurisdiction of the liberal arts college and leading to its bachelor of arts degree; postgraduate studies in professional engineering, industrial administration, and advanced engineering science are left to the engineering school.

The engineering science curriculums at Harvard and Dartmouth were designed and are staffed by their engineering faculties. Quite naturally, at this stage,

they tend to orient their students toward engineering careers. Similar unconventional curriculums but with wider scope are offered at the Massachusetts Institute of Technology and Rensselaer Polytechnic Institute amidst a plethora of conventional curricula, but these are administered by the schools' social science and humanities faculties. They are oriented more toward the social sciences and humanities.

The Dartmouth and Harvard programs require the engineering science major to take a set of basic liberal arts courses in common with all other liberal arts students. The MIT and RPI curricula require a student to take a block of basic mathematics, science, and engineering science studies in common with all engineering students before or along with a stronger emphasis upon social science and humanistic studies, i.e., an emphasis stronger than is obtained in the conventional engineering curricula at these institutions. They have been categorized as forms of liberal education polarized about the physical and engineering sciences.

The MIT curriculum, given under the aegis of its School of Humanities and Social Studies, leads to the unusual degree of Bachelor of Science in Economics, Politics, and Engineering. About 60% of the curricular time is allocated to basic science and engineering studies and 40% to the humanistic-social science studies. Its intent is to aid in the development of insights into the interwoven technical and non-technical problems of modern society. This seems to be the kind of education Senator Fulbright and others feel must evolve as a form of general education if we are to have an educated class who can understand what our scientific experts are up to. This course permits one to make connection with a career in "research, engineering, personnel, sales, promotion, international departments of business, and in government and labor organizations." It is also said to be sufficient preparation for graduate work in economics, engineering, business administration, law, and medicine.

At RPI, "the oldest engineering school in the English speaking world," a School of Humanities and Social Science was established in 1958. Major studies in economics, language and literature, philosophy, and psychology are offered as topping studies to two years of engineering courses. The degree offered is the bachelor of science.

Three-two Programs

The combined five-year programs, in which a student spends the first three years in a liberal arts college and the next two in an affiliated engineering school, are at the present slanted solely toward engineering. There are now over 160 independent liberal arts colleges—not including junior colleges—which have established liaisons with about 30 engineering schools. In effect the liberal arts college accepts one year of work in mainly the engineering sciences, taken at the engineering school, as fulfilling its degree requirement for the bachelor of arts degree. The engineering school then offers a bachelor of science degree for one year of postgraduate studies in some field of engineering.

For the student who places some value on campus activities and associations, the combined plan is not particularly attractive, since he must leave his liberal arts college at the start of his senior year, a time of his optimum social influence. It would certainly be more attractive to more students if their liberal arts college were to adopt departments of engineering science, as has been done at Harvard and Dartmouth, and proceed toward the development of their own brands of "techno-humanistic" education, as has been done at RPI and MIT. Specialized education could be deferred to postgraduate study in engineering, science, or non-science graduate schools, or to the industrially sponsored educational programs, "the new force in American education," which should be economically attractive to a graduate with a bachelor's degree.

All accredited engineering curricula today are required to devote about one fifth of the curricular time to bona fide humanistic and social science courses. Such courses as accounting, management,

and personnel administration are specifically excluded from this category. It is customary to have such courses taught by liberal arts college graduates in the liberal arts college manner. But there has been a growing dissatisfaction with the incohesiveness of these courses. There is vigorous experimentation to develop a more meaningful block of cultural studies. At Stevens Institute, Case Institute, Purdue, MIT and others, the engineering student is exposed to solid and intergrating studies of the foundations of western civilization. This serves as counterpoint in succeeding studies of the problems of modern society. This is suggestive of the idea behind Alexander Meiklejohn's Experimental College (University of Wisconsin 1926–38), an educational venture which in its time was considered too progressive for most liberal arts faculties.

There has also been some progress made within engineering education in using history as an instrument to integrate the social, economic, political, scientific, and personnel factors which have influenced the direction and pace of engineering progress. Many engineering authorities are writing and offering courses on the humanistic histories of the development of their special interests.

It seems probable that from the convergence of liberal arts and engineering education, two curricular variants may emerge. One, with an engineering orientation, shall move engineering education closer to the science major offered in the liberal arts college. The other, at a less mathematically sophisticated level, may develop into a form of rigorous general education which may be productive of disciplined minds which shall be aware of the material roots of their well-being as well as their cultural heritage.

It is from this convergence that good prospects may evolve to relieve what Sarton called ". . . the ominous conflict of our times . . . the difference in opinion, and outlook between men of letters, historians, philosophers—the so-called humanists on one side, and scientists on the other."

CHEMICAL ENGINEERING AT RUTGERS

A degree program in chemical engineering will be offered for the first time in the Rutgers College of Engineering, beginning next fall, it has been announced by Dr. Mason W. Gross, president of the State University.

Dr. Gross said allocation of $5,500,000 of College Bond Issue funds for the expansion of engineering facilities, including a new engineering building on the University Heights campus, "has enabled Rutgers finally to start a chemical engineering curriculum after more than 10 years of hoping and planning."

Dr. Elmer C. Easton, dean of the College of Engineering, has announced that Rutgers will accept a record 420 freshmen in engineering next fall in anticipation of the facilities which will be available in proposed new buildings for engineering, chemistry and physics. The buildings which will be financed by Bond Issue funds, are scheduled to be ready for occupancy by the fall of 1962.

Dean Easton said the enrollment increase next fall, from 350 to 420 freshmen engineering students, is based on a temporary expansion of laboratory space in physics which offers courses required of all engineering students.

By 1962, when the new engineering, chemistry and physics buildings are scheduled for operational status, the freshman engineering enrollment could grow to more than 600 students, Dean Easton said.

Dean Easton said the College of Engineering will proceed immediately to recruit a faculty for the new chemical engineering program. Course offerings in the first two years of the program "are practically in common with all engineering fields," he said, "but we will need a full-fledged faculty by 1962."

The Integrated Program in the Humanities and Social Sciences

WELLER EMBLER

Professor of English, Head, Department of Humanities, Cooper Union

This paper is essentially a summary of what we have learned at the Cooper Union from our experience over the past fifteen years with an integrated humanistic-social program. The omissions, the mistakes, the flaws in our philosophy of integration will perhaps be apparent; but this survey of what has happened in the Department of Humanities at the Cooper Union, this backward glance, shows that there has been some measure of success. There has been, at least, a consistency in our plan for a humanistic-social education for our students. If the implementation of the ideals has not taken place in every phase of our work, it is because we have not yet had time to fashion the fully integrated structure.

Because it is not intended that engineering students shall become specialists in some one of the humanistic or social science disciplines, the educational aims of the humanities and social science teacher in an engineering school are somewhat different from those of the engineering science teacher or from those of the teacher in the liberal arts college who devotes his time to working with students in a special branch of liberal-arts learning.

In the humanities, the teacher's aim is to broaden the student's interests, so as to protect him against too narrow a professionalism. The engineering student should have as a part of his undergraduate academic experience an introduction, at least, to the manifold ways in which man deals with his world of reality, an awareness of the strategies which man uses to make himself a home in the world —as poet, political thinker, manufacturer, linguist, historian, craftsman and builder, theologian, botanist, lawmaker, doctor, engineer, philosopher. The purpose of the humanities and the social sciences in an engineering curriculum is to make these various approaches to reality meaningful, enriching, and useful throughout the student's life. There is more than one way of dealing with what we call the real; and the mark of a broad education is an extended sympathy with, and some knowledge of, strategies other than the one in which we ourselves have been most thoroughly trained. In addition, the educated man will see that there is a relationship, sometimes very close, among the various approaches to reality, and that the total experience of being in the world cannot be reduced to the intellectual orientation of a single, independent discipline.

But every educator faces the problem of time, especially in our day of specialization. How shall justice be done the subjects of humane learning, massive in themselves, in the little time that can be devoted to them in an engineering college education. The technique of integration is one valid way of building a curriculum in the humanities and social sciences for professional students which will make possible a wide range of learning in a limited amount of class time, and also provide for a creative approach to the materials of study. The integrated program in the humanities and social sciences has to be thought out as a pattern extending through four years of undergraduate study. This means that careful thought has to go into curriculum build-

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ing on the part of the humanities and social science teachers. There are several major principles which should be taken into account in preparing an integrated program of humanistic-social studies.

1. *At least one humanities or social science subject should be required in each semester of the undergraduate course.*

In a four-year undergraduate program for professional students, it is important that a humanities or social science subject be required in each of the eight semesters. The student should participate in some branch of humanistic learning throughout his college life, so that he may sustain a continuing interest in the literature of human experience. The subject matter itself and the treatment of it should move from the relatively simple in the first year to the more complex in the last year; and there should be a revealed interconnection and an integrated relationship among all the subjects from the first through the last years. Though the humanities and social sciences may not move in serried ranks throughout the four years, there should nevertheless be a coordination of subject matter and treatment that is understood by the entire teaching staff and pursued as an ideal in theory if not one always attainable in practice.

2. *The humanistic-social program should be carefully planned by all the members of the faculty who are teaching the humanistic-social studies.*

Order is essential in learning. In preparing an integrated program for the humanities and social sciences, there ought probably to be some premeditated pattern to the plan of study, so as to ensure growth and steady enlargement of the student's intellectual life. Since in an integrated program a subject is not taught solely for mastery of content or of method, some preconceived framework, some scheme of guidance through various contents and methods has to be worked out in advance by the teaching staff. The aim is, of course, to coordinate the humanities and social sciences into one four-year humanistic-social experience. The liberal-arts subjects are, as it were, bound together into a single subject—the humanistic-social discipline. The schemes for integration may be chronological, or comparative, or methodological; or they may be developed in terms of the history of ideas, the survey, close linear examination of texts, or projects. Whatever the plan, care should be taken to avoid superficiality of treatment. It is quite possible to so organize a humanistic-social program that depth of study where depth of study is essential alternates with survey treatment where the survey plan is appropriate. Close linear examination of certain materials is important; but so also is the broad view. The two methods can be combined in a planned program, emphasis being determined by the materials selected for study and by the goal or aim of the integrated program as thought out by the teaching staff. It will be objected that there are bound to be serious omissions of content and method in an integrated structure. This is perhaps inevitable. Some of the materials for study ordinarily assumed to be valuable will have to be sacrificed for want of time and proper motivation. It is the responsibility of the entire teaching staff in the humanities and social sciences to determine what shall be omitted in order to make room for that which in the estimation of the staff is of greater value in terms of aims throughout the four undergraduate years.[1]

[1] Suppose in the building of a humanistic-social curriculum there are only six credit hours available for the study of economics. The entire teaching staff in the humanities and social sciences should decide what the content and scope of the studies in economics shall be. Shall the course be a principles course, or a course in the history of economic thought, or a course in economic institutions, or in economic analysis, or in economic theory, or in a combination of these approaches? If all approaches are combined, little depth in any one will be achieved; if only one approach is used, the student will have no acquaintance with the others. The teaching staff will have to decide what is most valuable for the student in terms of the entire four-year humanistic-social program.

3. *An integrated program in the humanities and social sciences encourages the student to be creative with the materials of his courses.*

In order that the greatest benefit may come to the student's intellectual life from his humanistic-social studies, the student should be encouraged to do something creative with the material he studies. He should be urged to work on projects (e.g., term papers) which call for a close contact with his materials. His analysis of the construction of a Greek temple, in the form of drawings, measurements, photographs, etc., will give him a subtle understanding of the "meaning" of a Greek temple, of the religious and cultural ideals embodied in the temple. (The accumulation of a body of miscellaneous information about a subject is not the aim of an integrated course in the humanities.) It is important that the student select for thorough inquiry some aspect of the work he is taking up in a course and to pursue research on his own, dealing always intimately, i.e., creatively, with the material. In a course which I offer in contemporary literature, painting, and music, a senior elective, my students have engaged in research that calls for their dealing directly with the materials under examination. In addition to their reading, some have taken part in extra-curricular dramatic productions, some have planned record concerts, some have made small collections of slides of modern paintings, have in one or two instances made their own slides from their own photographs, have edited small anthologies of poetry, have made photographic essays (complete with commentary) of selected examples of modern architecture. The possibilities for doing something with the materials of a course are numerous; the purpose of working on a project is to possess for oneself the ideas involved, to earn possession of them, as it were, by using them, by doing something with them.

4. *An integrated program in the humanities and social sciences puts emphasis on the concrete, on specific materials —on source readings, on original materials, on actual objects of art, on artifacts, attendance at dramatic productions, concerts, museums, on field study in the social sciences.*

Principle number 4, as I have outlined it, is closely related to principle number 3. But here I am requesting the teaching staff, in the building of an integrated program, to place emphasis on concrete materials. This emphasis on the concrete will correct any tendency to vagueness in the presentation of social-humanistic literature and ideas. The student should have positive experience of knowledge. In his study of the drama, the student should attend the theatre; in his study of music, the student should attend concerts; in his study of government and social institutions, the student should work in the field so as to test the theories he has studied with the facts as he finds them; in his study of painting, the student should look at original paintings; in the study of American history, for example, the student will profit by reading original documents, by visiting restorations, by working with artifacts in museums. In studying poetry, the student will grasp poetic meaning more readily if he is encouraged to do something with specific poems, if only to read them aloud, to memorize a poem, or better still, to write one himself. In thus urging an emphasis on the concrete, on individualities, as it were, I am taking for granted the customary thorough reading and study of books. For the study of books is in the end the most important feature of all our work. Being concrete is not a substitute for reading but a supplement to reading that gives dimension to reading itself. An integrated program calls for a familiarity with concrete items of cultural intellectual interest—with, for example, a Cellini cup, a Beethoven Concerto, a Dürer print, a Byzantine mosaic, the Constitution of the United States, a Cezanne painting, a Gothic cathedral, a Coptic textile, a Doric column, an engraved 16th century suit of armor, a New England church, George Inness' painting of Washington Irving's "Sunny-

side," the Dixieland "St. James Infirmary," the United Nations Buildings. Very nearly any detail will yield meaning if we experience it philosophically to see how it fits into the whole pattern of life. The humanistic way of life calls for a kind of philosophical concreteness, an awareness of the total environment, which is surely an aim of any education. The principle of concreteness in the humanities is the principle of looking outside oneself on purpose to knowing.

5. *An integrated program in the humanities and social sciences requires a learning environment that provides for as many intellectual influences as possible.*

Well-stocked libraries, exhibitions, theatrical productions, concerts, special lecturers, fine films, slide collections, recordings, and listening rooms, extra-curricular activities—an abundance and a variety of intellectual stimulations should be a part of the college environment of any professional school. If the student wants to make use of his environment, it is there for him. Part of this environment is, of course, the teaching staff itself; and in departments of humanities, of social sciences, of English, it is an advantage to have a staff with varied interests and educational backgrounds. This variety will make possible support of student interests in many different fields, will stimulate curiosity, will grant access to knowledge, and will provide rich and spacious surroundings for the cultivation of the humanistic way of life, which in many ways is the creative way of life.

6. *An integrated program places emphasis in value-judgments, on freedom of interpretation, on intellectual growth through the student's own efforts of analysis and judgment.*

We must take into account the difference between that which an engineering student is supposed to gain from a study of the humanities and that which, for example, the English major gains from the study of literature. The English major is required to know and to remember what scholars have said about the masterpiece of literature he is reading. He learns to apply certain standard interpretations to the literary works he is studying. The more thorough he is, the more he will know about what others, especially the scholars, have said about the masterpiece. The English major is, as it were, studying to be a professional man of letters, and it is essential that he be closely acquainted with a body of critical commentary, with glosses, analyses, exigeses, interpretations.

The plan of study and the intended goal in the humanistic program for engineering students is somewhat different. The purpose of an integrated program is to bring the student as close to the masterpiece he is studying as possible and in addition to reveal to him the interconnections among the masterpieces of a certain cultural era. The student comes to the masterpiece free of conventional explanations, free of critical preconceptions and predilections. His attention is directed to the work itself, for as much as he can make of it with such intellectual equipment as he has, at the time, attained to. The work he is studying means to him whatever it means at the time of his reading, with, of course, the help of the teacher, who may himself be a professional man of letters. In short, the engineering student studying the humanities has a rare freedom, the freedom to make of what he reads what he will, to be creative. He may not know what the experts have said about the work, he may not know the standard and conventional commentary of Milton's *Paradise Lost;* he knows only what with the help of his teacher he has found for himself in *Paradise Lost.* Often this enviable freedom makes possible a rare intellectual freshness which surprises new, vivid, revealing insights.

But this emphasis of freedom of judgment, particularly on the freedom to make value judgments, carries with it certain risks. If the student is asked to search for meaning in what he reads and studies, to search, that is, for humanistic meaning, humanistic because it has to do with human experience, he finds, often to his dismay, that unlike his technical

and scientific studies, there is no one absolute meaning or interpretation to the works of literature, history, philosophy, or art he may be studying. Humane learning does not lend itself to exact measurement. The student will learn that there can be as many interpretations of a work of literary art as there are readers. And this discovery can be distressing. The intellectual, creative freedom which goes with the multi-valued orientation may appear, in the pursuit of certainties, to yield but a dusty answer; and wearied out with contrarieties, the student may give up esthetic judgments in despair.

On the other hand, though there are hazards in the pursuit of humanistic knowledge, there is also intellectual adventure of the most rewarding kind. The freedom to think *about* the work of literature, or of philosophy, or of history, or of art is very valuable. The freedom to hew out roughcast thoughts and then to fashion them with the skill at one's command is a learning experience which shapes and forms the value-judging part of the mind. And the freedom to discuss the consequences of an idea or a thought, as though they were being discussed for the first time by anyone, is sound method for increasing the creative power of mind of the student. Moreover, in the development of taste—in the realization of the possibility of choice and of the responsibility that goes with choice—the student will be assisted by those works of man's mind and imagination which have been found worthy of preservation; but he will find them most valuable if he is encouraged to search for himself the reasons why they have survived. Of course, the student needs help, and his teacher works with him to serve as guide and counsel. Students and teacher, then, will be their own creative critics as they deliberate the meaning of Sophocles' *Antigone,* as they sound the deeps of *Paradise Lost,* or judge the shrewdness of the Wife of Bath's observations on what it is that women most want. Whether it is Burke's *Reflections on the Revolution in France,* or the philosophy of John Dewey, or the message of the *Book of Job,* or the character of Hamlet, or the meaning of Platonism, the subleties of an impressionist painting, the style of a rococo ceiling, the reticence of a Renaissance ayre, the puritanism of *The Scarlet Letter,* the depth psychology of Sigmund Freud, the meaning of Arthur Miller's *The Crucible,* the epistemology of John Locke, or the individualism of John Stuart Mill's essay *On Liberty,* the student is free to express his opinions, to form his judgment, to make what he will of his reading. He will have become familiar with that rich heritage of thought and things, prodigal of meaning, which will stand by him ever ready to be of service, unfolding new meanings and deeper insights as time goes on.

The gathering and weighing of empirical evidence is vital to human life, and the laws arrived at through the invariant character of a group of physical events are of inestimable value to mankind. Nevertheless, it has often been pointed out that the heart has its reasons as well as the head, that imagination, and intuition, and the creative spirit are very much a part of human experience, by no means the lesser part because their products are not always subject to exact measurement.

7. *An integrated program should be designed to encourage the student to continue with his learning and to persevere in his humanistic-social interests throughout his life.*

Whoever studies the humanities is a philosopher because he thinks about life as a whole experience and because he is constantly inquiring, probing, looking, studying, asking questions. This is perhaps the most distinctive feature of the humanistic frame of mind, this search for meaning, or, to put it another way, this search for the good, the true, and the beautiful. Learning for the philosopher never ceases; his formal education was perhaps only the beginning, a studying how to learn, how to look and listen, how to search. Most important of all in an undergraduate education is the inculcation in the student of *the wish to know.*

If our students graduate with the positive wish to know more, we have been successful with them, and they will live the humanistic way of life in its most distinguished and recognizable style—engagement in the unrelenting creative search for the good, the true, and the beautiful.

EXCELLENT TEACHING AWARD

An Excellent Teaching Award has been established by Clarkson College of Technology as a special recognition of the importance of superior teaching on its campus. The award will consist of a citation by the president of the college, Dr. William G. Van Note, and a check for $1,000. It will be awarded for the first time this spring.

In announcing the establishment of the award, to be made annually, Dr. Van Note outlined the basis for the award, as approved by the Faculty Council. He said the teacher to be honored would be selected for having demonstrated ability "to lead students to an understanding of the subject matter taught and its relationship to other disciplines, to help each student realize his full intellectual potential, to transmit the pleasure and satisfaction found in the pursuit of learning for its own sake and to encourage a desire in the student to continually search for knowledge and understanding, and to provide an example of rigorous intellectual integrity and courage."

Nominations of award candidates will be made by alumni in the second year after they graduate, in response to a special letter sent by the Alumni Secretary. For example, the class of 1958 will make nominations for the 1960 award. Each member of the nominating class may name one candidate and will send a supporting statement with his nomination.

The winner of the Excellent Teaching Award will be selected from the list of nominees by a committee of four members of the full-time faculty, two from the School of Engineering and two from the School of Arts, Science and Business Administration. These committee members will be elected annually by the faculty.

Winners of the award will automatically become members of the committee for the following four years and will become ineligible to receive the award for the succeeding four years. After four years of operation, the committee will be made up of winners of the awards in the four previous years, and it will thus become self-perpetuating.

NOW IT'S OFFICIALLY AUBURN

Last January 1 the name of the Alabama Polytechnic Institute was changed officially to Auburn University. Auburn is the Land-Grant College of Alabama and has been known unofficially by this name for many years.

Who Am I and Who Are You?

ERWIN R. STEINBERG

Carnegie Institute of Technology

Before we examine the matter of how students of engineering and science can gain perspectives through literature and the kinds of perspectives they can gain, we should first inquire into the aims of undergraduate education—or at least how our topic relates to those aims that are relevant.

In his recent report for the American Council on Education, Edward D. Eddy, Jr. says:

> In the four years of continuing enlightenment, every course, every professor, every campus activity should make a contribution in its own fashion and degree to the examined life which now *is* worth human living. The result may be the beginning answer not merely to *Who is man?* but to *Who am I?* The educated student emerges with a sense of what it really means to be a human being.[1]

A few pages later, he adds:

> The college, we believe, finds its greatest contribution to the student in the Socratic theme that the unexamined life is not worth living.[2]

For these three interrelated questions—Who is man?, Who am I?, and What is life?—literature does offer perspectives. It is thus a vital part of the curriculum of any undergraduate institution.

I should like to indicate briefly how students in engineering and science can be led to explore such perspectives and what they themselves feel the results can be.

I must first, however, make my position clear. I do not think that the perspectives literature can supply are any different for students of engineering than they are for students of accounting or agriculture or home economics or psychology or secretarial studies. All these students live in the same world and as people have pretty much the same problems. Further, I do not believe that literature needs to be approached differently for any particular group of students, no matter what their major. I do believe, however, that the motivation we employ and the examples we supply are often more successful if we choose them with an eye to the students' interests than if we do not. This is an elementary concept of communication, and teaching is, after all, an attempt to communicate. When dealing with students of engineering and science, then, teachers of literature would do well to take some cognizance of their interests and language and of the fields of knowledge to which they owe their primary commitment. Let me give you an example.

Sometimes on the first day of a literature course I place on the still undefiled blackboard a small chalk dot and ask the engineering and science students in the class how they would "define" or "locate" that point. Invariably, of course, the answer is "by means of other points or of a set of axes." I then add additional dots and the traditional x and y axes, to the satisfaction and perhaps to the amusement of the students, many of whom obviously marvel at the naiveté of an instructor who can ask such elementary questions—and in a literature course, of all places. It is a credit to their bringing up that they humor me.

My next question, however, although seemingly still elementary puzzles them: "How do you 'define' or 'locate' yourself? Who are you?" The answer is once again obvious, but it takes considerable discussion to arrive at: for "other points"

[1] *The College Influence on Student Character.* (Washington, D. C.: American Council on Education, 1959), p. 169.

[2] *Ibid.*, p. 177.

substitute "other people"; and for "a set of axes" substitute "the standards set by our society." And again the students settle back looking smug.

Then I ask, "How many of you know a single person so well that he confides to you his real feelings: the fluttering or drumming of his heart; the hurdle that he sneaks around instead of going over; the daily rebuffs that he smarts under; the measure and color of his castles in the air? How many of you really tell anyone else the private thoughts that jig, skulk, or careen through your mind?" Rarely does anyone raise his hand. And before they see the trap that I have lured them into, I slam the door: "If you don't know who anyone else is, how can you tell who you are? Not only can't you locate point A; you don't know anything about points B, C, D, and E, by which you intend to define A."

After a few minutes of milling around, several of them rush for what appears to be another way out: the axes, the standards set by our society. So we use as test cases some of the Ten Commandments. "Honor thy father and thy mother." Have they never, I ask, been angry with their parents, disobeyed them, been disrespectful to them? "Remember the Sabbath day, to keep it holy." Have they never, I ask, desecrated the Sabbath by word or act of commission or of omission? We then examine briefly the standards of morality on campus, cheating on exams, obeying traffic and parking regulations. And we discover each time that although laws, regulations, standards—of any sort—are phrased in absolute terms, they seldom provide the absolute set of axes that the students expected them to. For it is not only the standard that is important, but to what extent people subscribe to it or deny it, obey it or dodge around it or violate it. In order to define himself then, to know who he is, a person must know almost as much about other people as he knows about himself. But the class has already agreed that this is impossible. No exit. Still trapped!

Then I crack an unsuspected door. Isn't there any place where a person *records* his innermost thoughts? Wouldn't such records serve as points to define and locate other points, to define and locate ourselves? Books! Some rush eagerly at the way out: literature can provide the information and perspective that they need to discover who they are. Most of the rest follow along, if not convinced at least willing to be shown. The remaining few drag grudgingly behind, feeling somehow that they have been tricked, but not knowing quite how to object. My job for the rest of the semester, then, is to help each student to see how literature does indeed supply him with a measure of the world in which he lives, of the people who inhabit it, and of himself.

Now that I have begun a course for you, let me take you to the conclusion of one to let you hear what the students themselves say about "Perspectives Through Literature." Several years ago, Dr. William M. Schutte and I ran a fifteen-week seminar in the modern American novel with the cameras of WQED, Pittsburgh's educational television station, peering over our shoulders. The members of the seminar were all regularly enrolled professional students at Carnegie Institute of Technology, from the departments of architecture, chemistry, drama, home economics, mechanical engineering, and printing management (two sophomores, one junior, and four seniors; two women and five men). For fourteen weeks these students attended this weekly seminar in "The Novel and Modern Living," in which they discussed Hemingway's *A Farewell to Arms*, Cummings' *The Enormous Room*, Fitzgerald's *The Great Gatsby*, Lewis' *Babbitt*, Wolfe's *You Can't Go Home Again*, Steinbeck's *The Grapes of Wrath*, Faulkner's *The Bear*, and Warren's *All the King's Men*. On the fifteenth week, when they discussed "The Uses of Literature," we taped the audio portion of the program.

We opened the session by asking them, "What good is literature anyhow?" Here are some of the things they said. A junior in printing management (and the only veteran in the group) began with, "It's a lot of fun to read, first of all." A senior in architecture said:

I find that it represents life to me, in the sort of form that I can perceive how life affects me. Many things that I live through as I pass through life are nothing, and when I read a book I suddenly see things that I have done before but never have thought about. And in this way books make me conscious of things that I usually do and show how I can do them better, or that I should not do them at all.

A senior in printing management objected:

An interesting novel doesn't necessarily have to be related to the individual. You don't have to see yourself in a book. It can be something that is completely abstract; it can be a fairy tale, and yet from the fairy tale you can extract something. And you don't even necessarily have to apply it to your own life. But you're constantly learning when you're reading, regardless of the nature of the book.

A sophomore chemistry major added a different idea:

Well, I think it's a sugar-coating on a sometimes bitter pill. Things that we might normally avoid—like history or psychology—when they're presented in the form of a novel, subtly work themselves into our mind as we read. In this course we've gotten a pretty fair acquaintance with life in America in the 'twenties, 'thirties, and 'forties and the different problems and feelings and ideas that the people had during those times, something that I don't think we could have gotten as well through a condensed course in history or sociology.

A sophomore in mechanical engineering said:

I see books not only as an outlet, as the opportunity for self-improvement that Ed mentioned, but also perhaps as an outlet in some cases for a particular problem. In a sense perhaps a form of rationalization is possible. By identifying yourself with a particular character, seeing that he suffers the same tribulations you do, perhaps working out the same solutions and having the same form of enjoyment out of life, you are sometimes able to derive more pleasure out of your own activities and to derive less pain from those disappointments that you get out of life.

Our senior in home economics jumped in with:

I get a tremendous amount out of a lot of these books. We feel—and I very definitely feel—that home economics is one way in which we can help people to express themselves, to become individuals. We've already recognized in our discussions on earlier programs that there are many areas in which we have to conform today. But your home is one place where you can and should express yourself. And when I read a book like *Babbitt*, where I see such standardization carried to extremes, I have to contrast what happens there with what I feel, what an ideal situation would be.

To which our student of architecture added:

There is another way literature may affect our professional life. Many times when we're doing something, for instance in a creative profession, we feel depressed because we just can't get what we want to get. And by reading novels, sometimes we see the same situation. For instance take a book like *Of Human Bondage*, where the hero gets into a profession for which he is not fit or he thinks he is not fit. When we read about him, it makes us feel better because we realize that there are other people that are in the situation we're in. We don't feel as bad as we did before.

And on it went[3]—"unsolicited testimonials" of the kind sought (and even bought) by Madison Avenue account executives promoting cherry-flavored, eighty-proof cough remedies or roomier, boomier, and zoomier status wagons. Only these testimonials never found their way into television commercials or onto violently colored posters in trolleys, buses, and subways. Old Fitzgurgle's Bourbon can be made attractive to all sorts of Americans. The concept of "Perspectives Through Literature," evidently, is the wrong kind of corn.

Let me offer one more testimonial, again, as it happens, from a course in the modern novel. This paragraph comes from the final exam of an attractive and perceptive young lady:

One problem which I must confess dismayed me was women's part in society and women

[3] For the entire discussion, see William M. Schutte and Erwin R. Steinberg, "What Good is Literature Anyhow?" *Journal of Higher Education*, June, 1958.

relation to man. Perhaps because I had not had a reading course in college before, I did not realize that this problem existed. I thought that men's views on women's purpose and place in society had changed with the vote for women's suffrage. Obviously after being assailed by the authors on one hand and the masculine members of the class on the other, this is a problem which is not nearly solved. And the trouble is that college educations seem to make matters worse instead of better. In most of the novels the woman's part was dismally servile in comparison to the man. Unless the woman were of the homey, doormat type of Catherine in *A Farewell to Arms* or the pretty but useless decoration of Daisy in *The Great Gatsby,* she ended up the cause of man's troubles, like Marjorie Carling in *Point Counterpoint,* or as ineffectual as Mrs. Dalloway. If this is the period of freedom of the individual advocated by Rupert and Rampion, what happened to the women? The women who were portrayed as wholesome, warm characters were very few. Even Mary Rampion only said the things she had heard Mark express. I don't feel exactly crushed myself, but it certainly makes me feel as though something is wrong when so many conflicts are expressed.

For each of the students I have quoted, literature offers some sort of perspective. Some of the students are so concerned with the pressures of their personal lives that they look to literature for situations comparable to the ones in which they find themselves. Others are able to go to literature for what we like to call "the broader view."

Specifically, then, what sort of perspectives can literature provide for the student of engineering and science or for any student? It can help him to explore important relationships: the relationships between man and his God, between man and his fellow man, and between man and his inner self. Within these broad areas, it can provide subject matter and context for exploring such human problems as:

the relationship of parents and children;
the relationship of men and women, including romantic love;
the relationship of man to the physical world;
the function and nature of religion;
the integrity of the individual;
free will and determinism;
respectability and conventionality;
class distinction;
materialism;
nationalism;
political democracy.

These, of course, are only a few.

I should add here that, although it may sound that way from what I have said, I am not recommending that literature be treated as a social science or be used as a nostrum or patent medicine for what has come to be called bibliotherapy. (Prescription for young man with obvious Oedipus complex: read *The Silver Cord* and take a short course in Philip Wylie. Prescription for illegitimate young lady who does not know who her father is: read *The Scarlet Letter* and *Silas Marner.*) Because I have focused on only one aspect of literature—its value in providing the student with perspective for living—I have stressed what some of you may feel is its utility. I think that we must also help the student to understand the artistic dimension of literature. But I would add quickly that we should approach art through meaning. For if meaning is not literature's only dimension, it is certainly its most important dimension. And through it, we can help the student to understand his fellow man, the world in which he lives, and himself.

NEW DEAN AT USC

Alfred C. Ingersoll, formerly Associate Professor of Civil Engineering at the California Institute of Technology, became Dean of Engineering at the University of Southern California on February 1.

Mechanics Division Bulletin

Executive Committee

A. Higdon, Ch.....1960	H. R. Lissner *.....1961	E. P. Popov.....1962
L. A. Smith.....1960	J. O. Smith.....1961	F. P. Beer.....1963
D. R. Carver.....1961	E. J. Marmo.....1962	D. C. Drucker.....1963

Secretary of the Mechanics Division: Carl H. Cather, Department of Mechanics, West Virginia University, Morgantown, West Virginia.

Editor: Arthur W. Davis, Department of Theoretical and Applied Mechanics, Iowa State University, Ames, Iowa.

Chairman's Message

ARCHIE HIGDON

Professor and Head of Mechanics,
U. S. A. F. Academy

Hats off to our Program Committee for a well planned program! Personally, I am very well pleased with the prospects of a fine program at Purdue in June 1960. Details on the program are included in this Bulletin.

Is the Division, and in particular, the Executive Committee, coming to grips with the real problems in mechanics?

Perhaps my first question should be—what problems do you want studied by the Executive Committee? For example, do you want a summer school for mechanics teachers in the near future? Our last one was at Iowa State University in 1950, and in my opinion it was extremely worthwhile. Do you want a real study of the pros and cons of vectors for undergraduate mechanics, or do you already have all the information you want on this subject? I find far too many opinions and too little specific information on the advantages of vectors for a beginning course. Last year we had some success, or at least experience, with "so-called" standard examinations in statics and dynamics. Many groups, such as the American Chemical Society, have developed widely used and presumably effective National Standard Examinations. Are we overlooking an important area for general improvement of mechanics teaching by not putting more effort in the development of examinations which can be used any time, anywhere and compared to results achieved at other engineering colleges?

These are only a few suggestions. What we really need is for each member of the Mechanics Division to write us a letter *now*, setting forth ideas and suggestions for study and action by the Executive Committee. To be of most value, such letters should reach us before the Annual Meeting at Purdue.

Mechanics Division Program at the ASEE Annual Meeting, June 20–24

Monday, June 20, 1960

6:30 p.m. Dinner: Executive Committee of the Mechanics Division.

Tuesday, June 21, 1960

2:00 p.m. Conference:

Presiding: Dale R. Carver, Head, Department of Engineering Mechanics, Louisiana State University, Baton Rouge, Louisiana.

* Division Representative on the General Council.

Speakers: Herbert R. Lissner, Chairman, Department of Engineering Mechanics, Wayne State University, Detroit, Michigan.
Title of talk: Biomechanics Research.

J. L. Meriam, Chairman, Mechanics and Design, University of California, Berkeley, California.
Title of talk: Variable Mass Dynamics.

Wednesday, June 22, 1960

12:00 noon Luncheon: Mechanics Division

Presiding: Archie Higdon, Colonel, Head, Department of Mechanics, U.S.A.F. Academy, Colorado Springs, Colorado.

Business Meeting.

Speaker: O. Hobart Mowrer, Research Professor of Psychology, University of Illinois, Urbana, Illinois.
Title of talk: A New Theory of Learning.

2:00 p.m. Conference:

Presiding: Fred C. Lindvall, Chairman, Division of Engineering, California Institute of Technology, Pasadena, California.

Theme: Substance and Objectives of Typical Curricula in Engineering Mechanics, Engineering Sciences and Engineering Physics.

Panel: Paul F. Chenea, Head, Department of Mechanical Engineering Purdue University, Lafayette, Indiana.

J. H. Meier, Manager, Applied Mechanics Solids Group, General Electric Company, Schenectady, New York.

Charles E. Taylor, Department of Theoretical and Applied Mechanics, University of Illinois, Urbana, Illinois.

4:30 p.m. Conference:

Presiding: Archie Higdon, Colonel, Head, Department of Mechanics, U.S.A.F. Academy, Colorado Springs, Colorado.

Theme: Use of 16 mm Color Films and Closed Circuit Television in Teaching Materials Laboratory.

Speakers: Charles O. Harris, Head, Department of Applied Mechanics, Michigan State University, East Lansing, Michigan.
Title of Talk: 16 mm Film "Calibration Experiment" Used in Teaching Materials Laboratory.

Harry R. Wetenkamp, Professor, Department of Theoretical and Applied Mechanics, University of Illinois, Urbana, Illinois.
Title of talk: Use of Closed Circuit Television in Teaching Materials Laboratory.

NEW ENGINEERING–SCIENCE LABORATORY AT CLARKSON

The construction of a $1.5 million Engineering-Science Laboratories Building at Clarkson College of Technology will begin about the middle of May according to an announcement made by President William G. Van Note. The building is expected to be ready for occupancy by the fall of 1961.

The 60,000 square foot building, designed for use by all departments of the college, will provide increased laboratory facilities, classrooms and office space for chemistry, electrical and civil engineering. Dr. Van Note added that it will fulfill Clarkson's current requirements for academic facilities as well as the additional needs that will arise as enrollment mounts. The college, with an enrollment of 1,535 today, expects to have 1,800 students by 1965.

The Place of Mechanics as an Essential Foundation of the Engineering Sciences

DONALD C. HAACK

Associate Professor,
Department of Engineering Mechanics,
University of Nebraska

The relationship between mechanics and the various degree-granting curricula of an engineering college is often debated, sometimes with considerable vehemence. There can be little doubt of the direct practical relationship with the parts of civil and mechanical engineering devoted to structural design, machine design and kinematics, but its relationship to some of the other curricula is less well established by direct practical need. It is the overall, broadly inclusive relationship to engineering that we wish to discuss here.

The advocates of a strong program in mechanics are sometimes hard-pressed to defend their position in the face of the growing body of specialized technical knowledge which must, supposedly, be packed into the short four years of an undergraduate curriculum. The real relationship of mechanics to engineering is quite simple and straightforward. This reason is often lost, however, in a barrage of rationalization attempting to justify its existence on the basis of practical application in every branch of engineering. For example, to say that every electrical engineer must take mechanics to be able to design the cross arm on a telephone pole or calculate the tension in a guy wire, or to say that chemical engineers need mechanics to be able to design a tank, are reasons worthy of neither utterance nor attention.

Presented at the Kansas-Nebraska Sectional Meeting, October 1958. Recommended for publication by the Mechanics Division.

The real relation of mechanics to every branch of engineering stems from the fact that precise concepts of force, torque, moment, energy, inertia pressure and other quantities common to mechanics, as well as the relationships between and manipulations of these quantities, are a fundamental part of competence in all branches of engineering.

It is no simple coincidence that virtually all science remained at a standstill until the fundamentals of mechanics were developed. Mechanics was and is an essential, integral part of every branch of science and engineering. Mathematics stood ready for over 2,000 years waiting to assist in the development of science. Elementary surveying and geometry date back to 600 B.C., Pythagoras lived before 500 B.C., Euclid 300 B.C. The Greeks at Alexandria not only knew that the earth was a sphere, but had measured its diameter with phenomenal accuracy well before the Christian era began. Yet science did not develop because men had not yet observed, defined, re-observed, correlated and finally conceived, in precise thought and precise expression, that body of knowledge called mechanics.

It is true that Archimedes (287–212 B.C.) developed the principles of the lever, center of gravity and buoyancy. But the philosophy of Aristotle became established as the scientific creed of the early Christian Church and the superstructure of science could not develop on a foundation of laws that did not agree with nature. There were occasional glimmers of light in the darkness. In the 13th century Roger Bacon lived, experimented and philosophized. He was 400 years ahead of his time. Leo-

nardo da Vinci (1452–1519) experimented, invented and, of particular interest to us, seems to have been the first to grasp the idea of the moment of a force. Copernicus (1473–1543) devised and published the heliocentric planetary theory, only to have his work declared a forbidden book. But the era of waiting was drawing to a close. Simon Stevinus (1548–1620) developed the principle of the inclined plane and the resolution and composition of forces by use of a parallelogram. Statics began to take form as a body of knowledge. And then, in 1564, Galileo appeared. His scientific productivity began about 1590. He experimented, observed, and set down what we now recognize as the laws of free fall. Dynamics was born. Eighteen hundred years after Archimedes, mechanics became a science, though another half century was to go by before Newton added his crowning achievement. Once this was done, it was as though a cork had been pulled from an inverted demijohn and science came rushing out to meet the world. It has been but 230 years since the death of Newton, but what an eon in terms of scientific developments.

To reiterate, mechanics was necessary to the development of the other physical sciences because very few of these sciences can be approached without precise connotations of what may be described as intrinsically mechanical phenomena. In this same way mechanics is related to all the fields of engineering. For, what student can be expected to understand pressure, or a force field, or inertia without a prior understanding of mechanics for its own sake? Who really understands energy or work independent of the mechanical concepts of these phenomena? A study of statistical mechanics, for instance, shows that mechanical energy and heat energy are not only equivalent but identical at the most elementary level. There are ample examples of this sort, each showing that mechanics is one of the essential foundations of each of the sciences which finds its applied expression in engineering. This is the true relationship of mechanics to all engineering.

There is no doubt that elementary mechanics can be and is taught at high levels of competence in college physics departments. The advantage of a mechanics department in an engineering college lies in the fact that each teacher is not only competent in the mechanics, but also in at least one branch of engineering.

One word of warning should be expressed with respect to the relationship of mechanics to the various curricula. Nine or ten semester hours are not too long a time to spend in the study of the fundamentals of this essential foundation of the engineering sciences. But the same nine or ten hours are less than well spent if the subject matter included is over-expanded at the expense of the fundamentals.

MELLOH NEW DEAN AT IOWA

Professor Arthur W. Melloh of the University of New Mexico faculty has been named Professor of Electrical Engineering and Dean of The State University of Iowa College of Engineering by the State Board of Regents.

Professor Melloh's appointment will be effective July 1. As head of the SUI Engineering College he succeeds Dean Francis M. Dawson, who retired in 1957 after 21 years as Dean. At the request of University officials Dean Dawson had continued serving while a successor was sought, but illness forced him to withdraw from active duty in the college early last year.

Statics and Dynamics in Undergraduate Civil Engineering Education

W. J. HALL AND J. D. HALTIWANGER

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University of Illinois, Urbana, Illinois

Since civil engineering is to a signifcant extent based on applied mechanics and physics, it is necessary that civil engineering educators periodically examine the undergraduate mechanics requirements with respect to their adequacy for undergraduate education as well as for postgraduate education, whether it be formal or otherwise. The primary purpose of this paper is not to make a detailed appraisal of the content of existing courses, but rather to examine the extent to which current mechanics instruction is fulfilling the needs of civil engineering education, and to make several recommendations relative thereto.

Examination of a typical civil engineering curriculum will reveal that a student may have as much as three to four semester hours of statics and dynamics in physics courses, three to six hours of the same in formal mechanics courses, followed by strength of materials, hydraulics, structural analysis, etc., in which the same principles commonly are applied repetitiously. This is not meant to imply that repetition *per se* is to be avoided; indeed, observation reveals that efficient educational processes require a reasonable amount of repetition. Unfortunately, it is impossible to define precisely the optimum amount of repetition in any curriculum because it depends on the caliber and motivation of the student as well as on the quality of the instruction. For very good students repetition of the same basic principles of statics and dynamics in physics, mechanics, and civil engineering courses is excessive and often may detract from the student's interest or motivation. On the contrary, it seems probable that no amount of repetition would be sufficient to enable the very poor student to apply properly these basic principles, even though he may have successfully learned correct statements of them.

Since the present curricula have evolved over a good many years into a rather systematic pattern throughout the country, it might be concluded that the current offerings have been considered to be more-or-less satisfactory in the case of the "average" student. The validity of this conclusion can only be resolved by experimentation and observation. In this connection, the interpretation of the results obtained even in "controlled experiments" may be controversial, but this is no reason to avoid experimentation.

Experimentation

Recently we have seen some results of experimentation of this nature at Michigan State University.[1] In this experiment, two groups of sophomore mechanical engineering students were observed. One group had the regular course in mechanics in physics (hereafter often referred to as physics) followed by the normal applied mechanics sequences (statics and dynamics, hereafter referred to as mechanics). The other group bypassed the physics course and took only the mechanics sequence. It was concluded, among other things, that a C

Presented at the June, 1959, Annual Meeting of ASEE, at the University of Pittsburgh. Recommended for publication by the Mechanics Division.

[1] J. D. Ryder, "An Experiment in the Reduction of Physics Content," JOURNAL, Vol. 49, (November, 1958), pp. 118–121.

student received a grade of C in mechanics regardless of whether or not he had taken the physics course. In short, this limited study gave no indication that because a student had mechanics in physics he performed better in the mechanics sequence, and seemed to indicate that "once a C student always a C student." There is a possibility of course that even though the same grade was received by comparable students in each group, the level of proficiency obtained by the student who had the full sequence of courses was somewhat better than that of the student who had taken only the mechanics sequence. To ascertain properly the value of repetition in physics and mechanics would require following the progress of a large group of students for an extended period of time, perhaps even after graduation.

It is encouraging to see some experimentation in this area and it is recommended that more experimentation of this and perhaps other types be undertaken to evaluate the effectiveness of instruction in statics and dynamics. However, even without extensive experimentation programs, it is easy to make some general observations relating to this particular problem. For example, insofar as the material given in mechanics and physics is concerned, some repetition is necessary from course to course, but it can be questioned whether the mechanics instruction should be presented, as is often done, on the assumption that the student is starting from scratch. The necessity for doing this is sometimes attributed to the fact that different systems of units are used in physics and mechanics instruction, namely the CGS and English systems. While recognizing the desirability for familiarity with different systems of units, it seems rather expensive insofar as time is concerned to provide the student with this familiarity by repeating in mechanics essentially the same material covered in physics only with a different system of units. This problem may seem minor, but actually in many cases it serves to obscure in the student's mind the more important aspects of the areas under study. One obvious solution to this dilemma is to promote coordination between the physics and mechanics departments as suggested later, or under the present course organization to institute a short transition period wherein the relationships of different systems of units are demonstrated.

In other words, on the present basis should not some advantage be taken of the fact that the student has had rather extensive instruction in statics and dynamics previously in physics? The same observation can be made regarding the extent to which the material presented in physics and mechanics is repeated still again in the elementary structural analysis courses that are given as a part of civil engineering curricula. As a particular case in point, consider the computation of reactions for structures subjected to external forces. Examination of typical course outlines reveals that this material has been covered in some detail in physics, is repeated identically and perhaps in some cases not even as thoroughly in the mechanics sequence, and again is emphasized and repeated in detail in the beginning structural analysis course in civil engineering. There are some special applications that are considered in structural analysis courses which, for various reasons, do not commonly appear in the earlier courses, as for example the three-hinged arch; however, there is a question as to whether this is really a special case. Since all that is involved is the application of the equations of equilibrium, there would seem to be no reason why this case should be singled out for special attention in the earlier courses or moreover even in the structural courses. In fact, singling out so-called "special cases" may lead the student to believe that these are particularly difficult when on the other hand they are nothing more than routine insofar as application of the principles is concerned.

Need for Coordination

In examining the material presented in the various courses, one obtains the impression that it would be highly desirable for the staffs of the civil engineering, mechanics, and physics departments to coordinate their efforts. A study of some typical course outlines for statics and

dynamics covered in physics and in mechanics reveals a significant amount of parallel coverage, almost hour by hour in some cases. If the courses are considered individually it is apparent that the student receives only an hour or two of instruction in any one topic in each course. When presented piecemeal the principles commonly are remembered as abstract formulas or procedures not really connected in any way, each topic being in a separate realm as if it were a subject in itself.

Considering the courses together there seems to be ample time allotted, on the whole, for more efficient coverage of the subject matter. If this observation is correct, then it should be possible within the present time allocation to reorient the courses so that the student would have a better understanding of the subject matter, at the time he has finished this sequence of courses, than he does under the present arrangement. In arriving at such a new set of courses or realignment of existing courses it might be helpful to keep in mind the framework of coverage prepared by the Follow-Up Committee on Evaluation of Engineering Education —Mechanics of Solids.[2]

It is interesting to note that after the draft of this paper had been prepared an article appeared in the JOURNAL,[3] that reflects the same general picture noted above.

As one possible example of better utilization of time and change in method of instruction, refer again to the computation of reactions for some type of structural system. This subject would normally have been introduced in the mechanics course in physics, as a part of the consideration of the equilibrium of forces. With an introduction to this material in physics, it is undoubtedly desirable to consider it again, perhaps within a slightly different framework, in the mechanics sequence. However, would it not be possible and desirable in the second course to extend the discussion to include consideration of both external and internal force systems? By this is not meant merely axial stresses in bars as might be exemplified by ideal trusses, but instead such things as the internal force systems that are necessary to maintain equilibrium in beams, trusses, frameworks, etc. Commonly it is believed that a student should have a rather thorough understanding of the concept of stress and its implications before studying the internal force systems in a beam. However, this may not be a necessity when presented in the manner noted and might lead to a more realistic and easier understanding of what is meant by stress distribution. This would serve a two-fold purpose in that it would provide an early introduction to material that commonly is not considered until the student receives instruction in strength of materials and at the same time would give depth and breadth to his understanding of the necessary conditions of static equilibrium of force systems. In turn an early introduction would provide a better foundation for the assimilation by the student of material given later in strength of materials and elasticity, and might well make it possible to incorporate into the undergraduate strength of materials courses a substantial part of the theory now commonly appearing in advanced mechanics of materials courses.

Likewise, almost the same comments could be made regarding the use of previous material in the introductory structural analysis courses in civil engineering. Using the same example of reaction computations for structural systems subjected to external forces, why is it necessary in the civil engineering courses to dwell on this subject for an additional two or perhaps three weeks? Indeed this time might better be spent elaborating on other topics such as shear, bending moment, torsion, etc. that normally would have been presented in a basic manner in the earlier mechanics and strength of materials courses. If this plan were followed, the coverage given in the civil engineering courses would be enhanced, with the result that a better grasp of the

[2] "Report of the Follow-Up Committee on Evaluation of Engineering Education, Mechanics of Solids," JOURNAL, Vol. 49, (October, 1958), pp. 39–44.

[3] R. J. Seeger, and E. Weber, "Report on Physics in Engineering Education 1958," JOURNAL, Vol. 49, (May, 1959), pp. 780–782.

entire subject should be obtained by the students. It might even be possible to provide the student with an introduction to the theory of elasticity earlier than is currently customary; from the standpoint of structural analysis and design this would be particularly desirable.

While commenting on this situation, it might be well to point out the obvious fact that preferably the subject matter should be taught by the most highly qualified staff members. However, this is likely to be just as difficult in the future as it is at the present time for the simple reason that in many cases the time and interests of these men are directed toward advanced teaching and research. Moreover, the very large number of students that must be funneled through the basic undergraduate courses makes it almost impossible, particularly in the larger schools, to consider senior staffing of most of these courses. From a practical point of view it is necessary to use inexperienced young staff members, frequently teaching assistants and students who are working on advanced degrees. By their very nature, many of these young men do not have as their primary goal the effective teaching of the students entrusted to them, but instead are more concerned with their own personal immediate advancement. The solution to this particular problem is obviously very complex but may tend to resolve itself as improved economic conditions permit more highly qualified teachers to be retained in the teaching profession.

Constant Improvement

With respect to general educational philosophy, all university departments should be striving constantly to improve their respective curricula. This requires that the basic courses be revised periodically to permit the subsequent changing of courses following later in the curriculum. If the students that enter the various types of industry are to perform satisfactorily within a reasonable amount of time, it is necessary that while in school they be given adequate education to meet the technological requirements of the times. This means that periodic examination and revision of sequences of courses as suggested above and occasional deletion of material made obsolete by advancing technology are required to create time for the introduction of new material as it arises.

On a personal note, at the University of Illinois within the past year we have revised our civil engineering curriculum. Through extensive critical examination of previously given courses, we have found it possible to delete a considerable amount of material and, by relying more heavily on the student's previous background, to provide a number of new offerings to meet the objectives of the new curriculum. By no means are we completely satisfied with the revised curriculum, and after a few years it is likely that we shall find further revisions desirable and necessary. Indeed such constant revision is a necessity if we are to keep pace with the times.

CIVIL AND MECHANICAL IN ONE SCHOOL

The Schools of Civil and Mechanical Engineering at the University of Pennsylvania, which have long been separate units, will be combined to form the Towne School of Civil and Mechanical Engineering.

According to President Gaylord P. Harnwell of the University, the action is being taken in recognition of the fact that a number of subjects, including structures, mechanics and fluid flows, are of common interest to students in both schools.

In addition, the merger will offer greater opportunity for the further development of instructional and research programs in engineering mechanics, aeronautics and other studies related to space, he pointed out.

The graduate program in engineering mechanics, now an inter-departmental program, will center in the new school, where the master of science degree in that field will be awarded.

It is expected that the jointure of the schools will be completed before the opening of the University's 1960–61 academic year in September, according to Dr. Harnwell.

The Elementary Torsion Problem

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In a recent issue of this JOURNAL[1] I discussed a solution of the beam bending problem which appeared to me to be suitable for presentation in elementary courses on strength of materials. This note is a discussion of the elementary torsion problem from the same point of view that was taken in the beam analysis. Since in most courses and texts on strength, the analysis of bending follows soon after that of twisting, there may be some advantage in presenting both problems in the same light.

1. *The Differential Equation of Twisting*

Let $\tau = \tau(x)$ be a distributed torque per unit length applied to a circular shaft, an element of which is shown in Figure 1.

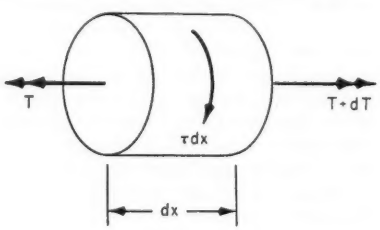

FIG. 1.

T is the total torque supported at a cross section. By taking moments about the axis of the element we find easily

$$-\tau = DT \tag{1}$$

where $D = \dfrac{d}{dx}$.

The differential angle of twist of the element of length dx is

$$d\theta = \frac{T dx}{GJ} \tag{2}$$

[1] "Deflection of Beams," JOURNAL Vol. 50 (Dec. 1959), pp. 273–276.

Combining equations (1) and (2) we arrive at the differential equation of twisting

$$D^2\theta = \frac{-\tau}{GJ} \tag{3}$$

Equation (3) is to the theory of twisting that the equation $D^4y = q/EI$ is to the theory of bending.

The solution of equation (3) is easily discovered to be

$$\theta = C_0 + C_1 x - \frac{1}{GJ} D^{-2}\tau \tag{4}$$

where

$$D^{-1} = \int_0^x \quad \text{so that} \quad DD^{-1} = 1.$$

The constants of integration are found by setting x equal to zero in equation (4) and its first derivative so that

$$C_0 = \theta(0) = \theta_0 \quad \text{and} \quad C_1 = D\theta(0).$$

Taking account of equation (2), however, we see that $C_1 = D\theta(0) = T_0/GJ$ where T_0 is the torque in the bar at the cross section $x = 0$. The solution of equation (4) may then be written in the form

$$\theta = \theta_0 + \frac{1}{GJ}\left[T_0 x - D^{-2}\tau\right] \tag{5}$$

which is in analogy with equation (4) of Reference 1.

2. *Examples of Twisting of Uniform Bars*

As a first example, consider the bar of Figure 2, loaded by a uniformly distributed torque over its outer part, and clamped at the left end. Taking the origin for x at the clamped end, we have

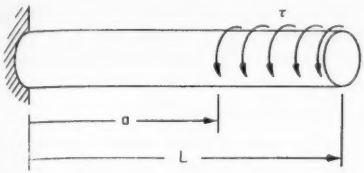

FIG. 2.

directly from equation (5):

$$\left.\begin{aligned}\theta &= 0+\frac{1}{GJ}[\tau(L-a)x] \quad \text{for } x<a,\\ \theta &= 0+\frac{1}{GJ}[\tau(L-a)x-\tau(x-a)^2/2!] \quad \text{for } x>a.\end{aligned}\right\} \tag{6}$$

As a second example, let the bar of Figure 2 be clamped at both ends. The torque, T_0, at the origin is now statically indeterminate, hence unknown. Then, from equation (5) we write

$$\left.\begin{aligned}\theta &= 0+\frac{1}{GJ}[T_0x] \quad \text{for } x<a,\\ \theta &= 0+\frac{1}{GJ}[T_0x-\tau(x-a)^2/2!] \quad \text{for } x\geqslant a.\end{aligned}\right\} \tag{7}$$

T_0 can be found from this last equation by setting $\theta = 0$ at $x = L$ on account of the clamping there. Hence,

$$T_0 = \tau(L-a)^2/2L.$$

As a third example, let us take the bar of Figure 3 with several concentrated torques acting on it, and clamped at both ends. This is a typical line shafting problem and is analogous to the bending problem of a beam clamped at both ends and carrying several concentrated forces. Again from equation (5), we write

$$\left.\begin{aligned}\theta &= \frac{1}{GJ}[T_0x] && 0\leq x\leq L_1,\\ \theta &= \frac{1}{GJ}[T_0x-T_1(x-L_1)] && L_1\leq x\leq L_2,\\ \theta &= \frac{1}{GJ}[T_0x-T_1(x-L_1)-T_2(x-L_2)] && L_2\leq x\leq L_3,\\ \theta &= \frac{1}{GJ}[T_0x-T_1(x-L_1)-T_2(x-L_2)-T_3(x-L_3)] && L_3\leq x\leq L_4.\end{aligned}\right\} \tag{8}$$

In these last equations, the origin has again been taken at the left end and the quantity T_0 is unknown since the problem is statically indeterminate. The details of the integration of the load function in this case are exactly the same as the integration of a concentrated load function in the beam bending problem discussed in Reference 1. The unknown torque T_0 is of course obtained from the condition of clamping at the right hand end of the shaft, so that, from the last equation:

$$T_0 = \frac{1}{L_4}[T_1(L_4-L_1)+T_2(L_4-L_2)+T_3(L_4-L_3)]$$

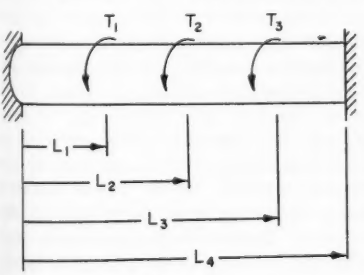

FIG. 3.

3. *The Concept of a Step Function*

The labor of writing equations for the case of discontinuous loads may be considerably lightened by the introduction of step functions and pulse functions. Define the step function Γ_a as follows:

$$\begin{aligned}\Gamma_a &= 0 \quad \text{if} \quad x<a\\ \Gamma_a &= 1 \quad \text{if} \quad x>a\end{aligned} \tag{9}$$

The product of a step function and an arbitrary function, $g(x)$, is

$$\Gamma_a g(x) = 0 \quad \text{if} \quad x < a$$

and

$$\Gamma_a g(x) = g(x) \quad \text{if} \quad x > a \qquad (10)$$

Making use of this concept we can write all four of equations (8) in one equation as follows:

$$\theta = \frac{1}{GJ}\left[T_0 x - T_1\Gamma_{L_1}(x - L_1) - T_2\Gamma_{L_2}(x - L_2) - T_3\Gamma_{L_3}(x - L_3)\right] \qquad (11)$$

In order to obtain equation (11) formally from equation (5) we need to introduce another discontinuous function, Γ_a' which may be thought of as the "derivative" of the step function. Γ_a' is the Dirac Delta Function, and has the following properties:

$$\left.\begin{aligned} \Gamma_a' &= 0 \quad \text{if} \quad x \neq a, \\ \int_{-\infty}^{\infty} \Gamma_a' dx &= 1, \\ D^{-1}\Gamma_a' &= \Gamma_a \quad (a > 0). \end{aligned}\right\} \qquad (12)$$

In terms of this new function we may write the distributed torque, $\tau(x)$, for the bar of Figure (3) as

$$\tau(x) = T_1\Gamma_{L_1}' + T_2\Gamma_{L_2}' + T_3\Gamma_{L_3}'. \qquad (13)$$

The particular solution, $\frac{1}{GJ} D^{-2}\tau$, of equation (3) is then obtained by twice integrating equation (13) from zero to x, i.e.

$$D^{-1}\tau(x) = T_1\Gamma_{L_1} + T_2\Gamma_{L_2} + T_3\Gamma_{L_3} \qquad (14)$$

and

$$D^{-2}\tau(x) = T_1\Gamma_{L_1}(x - L_1) + T_2\Gamma_{L2}(x - L_2) + T_3\Gamma_{L_3}(x - L_3) \qquad (15)$$

since

$$\int_0^x \Gamma_a dx = \Gamma_a(x - a).$$

Making use of equations (15) and (5), equation (11) can be written down directly.

It is perhaps redundant to add that the functions Γ and Γ' (and indeed, Γ'') find similar use in the beam bending problem.

4. Nonuniform Bars

In the case of a bar whose cross section varies along its length, equation (3) must be replaced by

$$D(kD\theta) = -\tau \qquad (16)$$

where k has been written for the torsional stiffness in place of GJ, so that (16) refers to a bar of any cross sectional shape. The first integral of equation (16) is

$$kD\theta = -D^{-1}\tau + T_0 \qquad (17)$$

and the second integral is

$$\theta = -D^{-1}\left[\frac{D^{-1}\tau}{k}\right] + T_0 D^{-1}\left[\frac{1}{k}\right] + \theta_0. \qquad (18)$$

An example of the application of equation (18) might be an airplane wing whose torsional stiffness k varies in a known manner and is subjected to a distributed torque τ which arises from the pressure over the wing area. In this case τ is also a function of the local twist angle θ and equation (18) is an equation of aeroelasticity. In most cases of this type an iterated process of graphical or numerical integration is necessary to solve (18). In many less complicated cases, however, equation (18) may be solved analytically.

5. Conclusion

It appears that strength of materials can be taught more effectively if there is a unity of method applied to the various problems treated in the course. In particular the procedure of obtaining a differential equation and its solution, and of studying that solution in detail which is so basic in all engineering analysis should be stressed. This method of handling torsion and the previously discussed solution of the beam equation seem to fit together very well in this respect. Further formal analogies exist, viz: the problem of stretching of axially loaded bars can be phrased easily enough

in terms of the equation

$$D^2u = \frac{p(x)}{AE} \tag{19}$$

where u is the displacement, $p(x)$ is the axial load per unit length on the bar, A is its cross sectional area and E is Young's modulus. Comparison of equations (19) and (3) indicates that there is an exact formal analogy between the twisting of a bar and the stretching of a bar, and this also may be worthy of some exploitation in the class room. If strength studies have been preceded by a course in dynamics, it is also worth while to mention the dynamic equation

$$D^2x = \frac{F(t)}{m} \tag{20}$$

$\left(\text{where } D \text{ now means } \frac{d}{dt}\right)$ for a particle of mass m acted upon by a force F which depends on time only.

NSF GRANTS FOR SUMMER CONFERENCES

The National Science Foundation has announced grants totaling approximately $275,000 to colleges and universities in support of sixteen Summer Conferences for College Teachers of Science and Mathematics. Although the title does not indicate it, two of these are directly in engineering.

The Conferences are designed to strengthen teachers' mastery of newer developments in science and mathematics and to help increase their effectiveness in the classroom. The more than 500 participants will receive stipends of up to $15 a day plus travel allowances. Stipend holders pay neither tuition or fees.

Participants will be chosen by the Conferences, *not* by the National Science Foundation. Inquiries and applications should be addressed to Conference directors. Early inquiry is advised. The engineering Conferences are:

Michigan		
Detroit, University of Detroit, Mich.	Prof. Paul M. Reinhard, Chairman, Dept. of Engin. Graphics	Graphics in Scientific Engineering
Missouri		
Washington University, St. Louis, Mo.	Dr. Gerald L. Esterson, Dept. of Chemical Engin.	Systems Engineering Theory for Chem. Engin. Teachers

How is Mechanics of Fluids Being Taught?

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Early in 1957 an *ad hoc* committee consisting of R. C. Binder, W. C. Nelson, Hunter Rouse, A. H. Shapiro, R. L. Sweigert, J. V. Vennard and V. L. Streeter, as chairman, made a short but important report on the desirable characteristics of undergraduate courses in mechanics of fluids. Because of its brevity and because there may be those among us who did not see it or whose memories are leaky, this report will be repeated as the basis for later comment.

Report of *Ad Hoc* Committee on Mechanics of Fluids

"Some need for an understanding of the behavior of fluids at rest and in motion pervades every branch of engineering, and the subject of fluid mechanics has reached an extraordinary degree of ramification. Specialized ideas and methods have been developed to meet particular problems in the field of civil engineering, mechanical engineering, aeronautical engineering, chemical engineering, meteorology and oceanography, acoustics, and magnetohydrodynamics. It is quite evident that an introductory course cannot begin to cope with this diversity. But it is equally true that there is a common core of fundamental ideas, conceptual models, and basic principles on which the diversity is built. Effectively grasped, this core endows an individual with the capacity and, even more, the intellectual courage, to approach problems in fluid motion with some degree of effectiveness and competence.

"The undergraduate work in fluid mechanics, whatever else it may do, should aim at this core of ideas, models, and principles. Moreover, it should do so in a manner which best arms the student to confront the variety of situations which, sooner or later, he must face. Although the cultivation of flexibility and generality is implied by these statements, this need not interfere with motivation and illustration in professional fields. The important thing in this balance is that practical examples are chosen and presented not alone for their own sake but for their aptness in demonstrating the use and power of the fundamentals.

"Within this context of general principles, the instruction in fluid mechanics could be given in any one of several departments, or in several simultaneously. Furthermore, provided that the content and spirit of the fundamentals here referred to are made an integral part, the undergraduate instruction may proceed in some depth along one of many directions.

"It would be self-defeating and devitalizing to avoid or to denigrate practical problems. But these should be introduced as an integral part of the scheme to create in the student a potential, in terms of intellectual and psychological fitness, for dealing with practical problems of increasing scope and variety.

"There is some paradox in the fact that, in order to equip students to meet many types of situations, one may be obliged to reduce rather than expand the amount of subject matter in the curriculum. This comes about because resourcefulness in an engineering science depends uniquely upon a firm grasp of those so-called elementary concepts and principles which are in fact the really difficult parts of any discipline. If they are indeed to be grasped, time must be taken to wrestle with them for their own sake, and this may require that somewhat less attention be given to particular problem-solving skills which have become traditional. What is asked for here is that we face the fundamentals squarely without evading their difficulties. This is the surest way toward engendering both confidence and ability."

Presented at the June, 1959, Annual Meeting of ASEE at the University of Pittsburgh. Recommended for publication by the Mechanics Division.

Essential Subject Matter in the Undergraduate Curriculum on Fluid Mechanics

"1. Introductory Material

This portion of the subject matter has a threefold task. First, to correlate the science of fluid mechanics with those engineering sciences directly related to it—primarily the mechanics of solids, but also thermodynamics and properties of materials. Second, to differentiate it from the others by virtue of the distinguishing properties and behavior of fluid matter. Third, to introduce on an elementary basis the aspects of dimensional reasoning which should be common to all engineering science but are most needed in fluid mechanics because of the various properties involved.

"2. Fundamental Concepts and Principles of Fluid Motion

The fundamental concepts are: velocity at a point, and the velocity field; stream lines; local and convective acceleration; mass density; normal and tangential stress; and body forces. The fundamental principles are: the principle of mass conservation as embodied in the continuity theorem; and the Newtonian laws of motion as embodied in the equations of flow, including the momentum theorem and the theorem of mechanical energy for regions of space.

"3. Effects of Fluid Inertia

Many of the important aspects of fluid motion may be introduced by investigating a model in which the only force influencing the motion is that due to pressure gradients. This may be explored at various levels including the elementary pressure-velocity relationship for unsteady or non-uniform flow, vortex motion, and irrotational flow.

"4. Effects of Fluid Weight

With the treatment of hydrostatic loading in the initial course in statics, the effects of fluid weight, or gravity, in fluid motion can be more broadly treated in terms of the three-term Bernoulli equation as a superposed hydrostatic pressure in confined flow and an accelerative force in unconfined flow. Free-surfaced conditions may be exemplified by deep-water waves, by open-channel phenomena, or by more general density stratifications in the atmosphere, ocean, or settling basin, with the Froude number as the key parameter.

"5. Effects of Fluid Viscosity

To the extent that turbulence is a viscous phenomenon, or that molecular and eddy viscosities are parallel concepts, this section includes both non-turbulent and turbulent motion. Particular emphasis is placed on surface and form resistance of immersed bodies and of conduits, with the Reynolds number as the key parameter, as well as highly viscous flows in which the fluid density is unimportant. Essential topics are laminar and turbulent shear, boundary-layer theory, form drag, resistance of smooth and rough surfaces.

"6. Effects of Fluid Elasticity

To the extent to which the compressibility of a gas can be treated like that of a liquid, this phase of flow belongs to fluid mechanics rather than thermodynamics. However, there are pertinent analogies between sound waves and gravity waves that should be understood in terms of the Mach and Froude numbers as key parameters. Moreover, the extent to which liquids and gases can be treated as incompressible with negligible error should be evaluated in terms of the simple gas equation.

"In every instance, emphasis should be placed upon principle and its widespread application. Such matters as manometers, Pitot tubes, and flow meters should be introduced as applications rather than as bases for flow classifictaion. Either laboratory or class demonstrations are important in presenting this material. Many laboratory periods or class demonstrations are not necessary. Quantitative demonstrations in which the students are given data to develop which they have seen taken are good. The laboratory work should require that the student develop his own methods of taking data, evaluating it, and discussing it in so far as it is practicable. All of the foregoing divisions are deemed essential to the engineering student's education. It is in their applications that the pedagogical flexibility and ingenuity lies."

With the foregoing report as a guide, a simple, 20-item questionnaire was sent to 166 engineering schools in the United States in an attempt to gain information as to the degree to which the recommendations of the report are presently being followed. Some intimation of the diversity which was to be revealed was apparent when it was found that only one-third of the schools addressed had a separate department of mechanics. This indicated that two-thirds of the fluid mechanics work is presented by degree granting departments which might well be expected to have a particular bias.

There was a good response to the questionnaire, more than three-fourths of them having been returned. Not all were carefully answered, as indicated by inconsistencies. Some questions were not sufficiently clear and one was garbled. However, because of the large number received, these difficulties tend to become ironed out and the general trend is apparent. The following table indicates the degree to which subject matter, concepts, principles, or pedagogic treatment are being carried out in relation to the *ad hoc* committee recommendations.

AGREEMENT WITH COMMITTEE RECOMMENDATIONS

	Per Cent		
	Yes	Partially	No
Background Matter			
Mechanics of fluids correlated with mechanics of solids and thermodynamics	83	10	7
Dimensional reasoning introduced	94	4	2
Fundamental Concepts and Principles			
Velocity at a point	94	1	5
Velocity field	75	8	17
Local and convective acceleration	59	11	30
Mass density	98	0	2
Normal and tangential stress	90	3	7
Body forces	90	3	7
Continuity of mass	98	0	2
Laws of motion, momentum, energy principles	98	0	2
Fluid Inertia			
Mass-pressure gradient relationship	62	11	27
Fluid Weight			
Use of Froude number	68	10	22
Fluid Viscosity			
Use of Reynolds number	91	3	6
Fluid Elasticity			
Use of Mach number	64	10	26
Teaching Methods			
Problems illustrate basic principles rather than develop applications	79	19 (both)	2
Demonstration or film	64		36
Accompanied or followed by laboratory courses	72	9	19

	No. of Depts.	Per Cent
Same course given to several departments (25 different departments involved)	0	19
	2	21
	3	21
	4	11
	5	5
	6	6
	7	2
	8	1
	9	1
	All	13

	1	1 + lab	2	3 or more
Undergraduate work given in following number of courses	62	15	17	6

A report was also received on the textbooks used, chiefly to help evaluate responses to the questionnaire. However, the replies indicate that a wide variety of books, more than twenty in number, are used; in some cases more than one text is employed in the same course—and, contrariwise, in four schools no text at all is used. Half a dozen books enjoy patronage at 85% of the responding schools, but no notion of the actual numbers of each in use can be given. A review of Professor Kindsvawter's survey on text needs in fluid mechanics conducted early in this decade indicates that the popular books of that time are still in use although there have been shifts in relative popularity and some newcomers in the field are forging ahead in adoptions.

The large number of disciplines requiring a course in fluid mechanics was somewhat surprising. At the schools reporting, the following departments are mentioned as taking fluid mechanics. No doubt there are still more who weren't identified.

Aeronautical engineering
Agricultural engineering
Architectural engineering
Ceramic engineering
Chemical engineering
Civil engineering
Electrical engineering
Engineering mechanics
Engineering physics
Engineering science
Geological engineering
Geophysics
General engineering
Industrial engineering
Materials engineering
Mechanical engineering
Metallurgical engineering
Mineral dressing
Mining engineering
Naval architecture
Nuclear engineering
Petroleum engineering
Planning engineering
Sanitary engineering

A review of the responses to the questionnaire shows a substantial shift in course content from the days of a generation back when at meetings such as this we debated whether or not a civil engineer should take hydraulics or fluid mechanics. Now practically all C.E.'s are taking fluid mechanics, although there are a few who are apparently sticking fairly close to the hydraulics of that day. However, attention can be drawn to the fact that many of the general relations or concepts such as velocity at a point, continuity of mass flow, energy and momentum principles, and Reynolds effects are covered in more than 90% of the courses presently given. In fact, nearly all of the committee recommendations are being given in two-thirds of the present-day courses. Furthermore, the frequent notation of a change of text for next year indicated an accelerated shift in the direction of the committee recommendations. It can be safely said that the great majority of schools are giving a general course which includes the modern concepts of dynamic similarity as indicated by such parameters as the Froude, Reynolds, and Mach numbers.

Many departments still feel that their students must have a course tailor-made for their needs rather than a general course. In 19% of the schools, each department had its own course, if any; and only one-eighth of the schools reported all departments taking the same first course in fluid mechanics.

In conclusion, it is apparent that at the present time fluid mechanics is not yet accepted as a fundamental course paralleling the solid mechanics courses, statics and dynamics. It is not given to all engineering students in the same form to anywhere near the extent that the solid mechanics courses are. (In fact, it is exceptional to find any major differences in the solid mechanics courses offered to different departments.) This can be readily understood when it is remembered that hydraulics as taught by the civil or mechanical engineering departments was the forerunner of fluid mechanics and the problems of these areas were naturally emphasized. However, the common core of ideas and concepts recommended by the committee are cer-

tainly being taught by an increasing percentage of American schools and the texts which emphasize the basic concepts have become more and more widely used.

The present status of fluid mechanics, therefore, may be regarded as an improving one. There is evidence of a rapid falling into line on a more general and scientific approach to fluid flow problems. On the other hand, there is still much room for improvement. Particularly essential is the conversion of more departments to the opinion that this course is as general and fundamental as a course in statics or dynamics and should be regarded in the same light.

SPACE SCIENCES LABORATORY CREATED ON BERKELEY CAMPUS

The establishment on the Berkeley campus of the University of California of a new Space Sciences Laboratory to delve into the scientific problems generated by the advent of space travel has been announced by President Clark Kerr and Chancellor Glenn T. Seaborg.

Samuel Silver, professor of engineering science, has been named director of the new laboratory.

Now in the process of becoming established, the laboratory will serve as an interdisciplinary facility.

Although the Regents of the University have provided a modest basic budget for the laboratory, primary support is expected to come on a contractual basis from various government agencies now providing funds for basic research in space sciences.

SCIENCE OF MATERIALS FELLOWSHIPS AT CARNEGIE TECH

The unique doctoral program in the Science of Materials established at Carnegie Institute of Technology in 1959 has been expanded by a second grant of $111,000 by the United States Department of Health, Education, and Welfare.

One of the relatively few engineering grants made under the National Defense Education Act of 1958, the original appropriation provided for the establishment of five fellowships in the fields of civil, electrical, and mechanical engineering. The new grant is enlarging the program by providing funds for fifteen fellowships, each worth a minimum of $9,600 with dependency allowances for three years of studies.

The Science of Materials Program provides the fundamental basis for studies in the application to engineering research of atomic, molecular, and solid state physics, physical chemistry, and molecular electronics. Candidates are being selected on the basis of outstanding careers in work leading to the B.S. degree in engineering fields.

Candid Comments

This section is open to comments on articles in the JOURNAL or on engineering education in general. Send comments to the Editor, JOURNAL OF ENGINEERING EDUCATION, University of Illinois, Urbana, Illinois.

Professionalism vs. Unionism

From the Dean's Page of The Iowa Engineer

The question is sometimes raised as to whether or not engineering is a profession. Is the engineer a professional man? In some parts of the country, successful attempts have been made to enlist engineers into the membership of labor unions. A small, but still significant, numbers of engineers belong to unions of technical employees. If the engineer is a professional man, can he at the same time be a good union member? Are professionalism and unionism compatible?

Let us first examine the differences between a profession and a trade. It is important to note that both professions and trades are useful, legitimate and honorable callings. Mankind could not progress without both. But there are differences between them.

Webster states that the term "profession designates the more learned callings, as the profession of a clergyman, a lawyer, a physician, a civil engineer, a teacher" while the term "trade applies to any of the mechanical employments or handicrafts except those connected with agriculture." Harry A. Winne, a retired vice president of General Electric, has summarized professionalism as being a composite of the following attributes: a background of education, a continual drive for more knowledge and understanding, a continual increase in competence, a readiness to serve above and beyond the extent which the immediate reward may seem to justify, a search for opportunities to guide and instruct younger and less competent people, and a posession of a very high standard of ethics.

A trade, on the other hand, is characterized as an occupation requiring manual or mechanical skill, training and dexterity. Historically, unions have been associations of tradesmen, of craftsmen, as is evidenced by their common characterization as "trade unions." Many unions have served the worker, and his employer, well. But do they have a place in the life of a professional man?

President Eric Walker of Pennsylvania State University has said that while unionism is concerned with the relationship between man and his boss, professionalism is concerned with the relationship between man and mankind; that unionism concentrates on rights and privileges, while professionalism concentrates on duties and services. The physician, the clergyman, the lawyer (whether in private practice or employed by a corporation) and the engineer (whether in private practice or employed by a corporation) is concerned first with the interests and welfare of his patient, his parishioner, his client, his employer. If he cannot approve of the objectives of his client, the ethical professional man does not accept proffered employment. The trade union, on the other hand, is organized to promote the welfare of its own members, often with little or no concern with the interest of the employer. It is in this regard that we first find that professionalism and unionism are incompatible. A man cannot serve two masters.

But, you may say, the engineer must look after his own interests. True, but should this be done through unions? Or, even more strongly, *can* this be done through unions? By the very nature of their primary concern with workers in the trades, unions are geared to deal with activities in which standards of production can be established and controlled. And

the objectives of unions are to establish uniform production; uniform pay, hours and fringe benefits; and advancement based largely on seniority. The engineer, however, is an individualist. He wishes to make his own decisions. He feels that individual accomplishment should be rewarded and that his promotion should be based on his own achievements. Here is the second incompatible aspect of professionalism and unionism. Unions tend to standardize on mediocrity; the professional man wishes to be free to advance to an extent limited only by his own abilities and his own contributions to society.

In 1948, Dr. William Wickenden, President of Case Institute of Technology, delivered a paper before the Engineering Institute of Canada which has become a classic in engineering literature. The paper was entitled "The Second Mile" and was based on a verse from the Sermon on the Mount—"Whosoever shall compel thee to go a mile, go with him twain." Dr. Wickenden said, "Every calling has its mile of compulsion, its daily round of tasks and duties, its standard of honest craftsmanship, its code of man-to-man relations, which one must cover if he is to survive. Beyond that lies the mile of voluntary effort, where men strive for excellence, give unrequited service to the common good, and seek to invest their work with a wide and enduring significance. It is only in this second mile that a calling may attain to the dignity and the distinction of a profession." Here, then, is a final difference and a final incompatibility between professionalism and unionism. The unionized worker is concerned only with the first mile; the professional man with both the first and the second mile. To make the most of his opportunities and of his life, the engineer must, and does, go the second mile.

GEORGE R. TOWN
Dean of Engineering
Iowa State University

NEW DEAN AT VANDERBILT

Dr. Robert Seaman Rowe, Professor of Engineering at Duke University, has been named Dean of the Vanderbilt University School of Engineering, where he will assume his duties next September. He succeeds Dean Fred J. Lewis, who died in January, 1959.

Dr. Rowe holds degrees from the University of Delaware, Columbia University, and Yale University. He taught at Princeton University before joining the Duke faculty in 1956 as Professor of Civil Engineering and Head of the Department. Since 1957 he has been J. A. Jones Professor of Engineering at Duke. He has been a member of ASEE since 1951.

YET-itudes

"Feedback" on Classroom Performance

DAVID V. HEEBINK

Assistant Professor,
Industrial Engineering Department,
Stanford University

It is unfortunate for students and teacher alike that there is no quick, objective way to evaluate the latter's classroom performance. Good teaching is extremely important both from the standpoint of efficiency in education and of personal job satisfaction. However, in the majority of cases an engineering teacher has only his subjective hunches to use as a guide to improvement. The goals of this article are to: a) show that there are some reasonably convenient ways to obtain constructive suggestions, and b) encourage the reader to seek such help if he feels the need for it.

Perhaps the most readily available indication as to whether an instructor is making himself clear is the behavior of class members. Yet this obvious source of "feedback" is too frequently ignored. A teacher often becomes engrossed in what he is saying, or perhaps is generally insensitive to other people's responses. Whatever the cause, an awareness of students' reactions *can* be developed if one devotes some effort to it. Moreover, it is invaluable in teaching, because it saves time by indicating whether the instructor is pacing himself correctly or not.

General evidence of boredom or lack of challenge indicates that either the pace is too slow or else the presentation is uninteresting. On the other hand, confusion can result from a pace that is too rapid or a presentation that is poorly organized.

Part of the art of sensing student reactions is predicated on "having a feel" for a particular class. Some classes register boredom or confusion in rather obvious ways, whereas other groups are more indifferent. However, even the most blasé class will contain a few responsive individuals. Once the teacher has recognized them and satisfied himself that they are a representative sample, he has a useful barometer.

Although classroom responses are helpful, there are other student reactions that can be useful to the teacher. For example, it might be interesting to know whether homework assignments are reasonable or whether the students find lectures well organized. Students are naturally hesitant about volunteering such information; so it is usually up to the instructor to take the initiative. There are at least two ways to query students. One is by means of a questionnaire near the end of a course. The other is by verbal questions after a course is over.

Questionnaires have several desirable features. One is that they can be anonymous; another is that a whole class can be polled in a reasonable amount of time. Of course, the questions that are asked must be well thought out if worthwhile answers are expected, and one must be prepared for the inevitable humorist when the answers are read. It has been the author's experience, however, that the vast majority of undergraduate students are remarkably candid and constructive in their answers to anonymous questionaires. Moreover, when a whole class is polled it is possible to check for the consensus of opinion on important items.

An interesting elaboration of the questionnaire technique is the department-wide or school-wide evaluation that is sponsored by honorary groups at some

universities. When correctly planned and executed, these ratings can provide an instructor with a quantitative appraisal of various aspects of his performance. Furthermore, if department or school averages are made available, a very objective comparison can be made with the rating of the average professor. Clearly, if such ratings are to be used constructively, they must be strictly confidential in a real-life situation.

Asking verbal questions is an easy way to do spot checking on rather impersonal aspects of a course. If a mature, frank student is asked in private how he found the homework load during the semester, he will very likely give a candid answer. Considerable discretion must be used in choosing the type of question that is asked. Queries pertaining to the instructor's classroom performance, *per se*, would certainly be inappropriate in a face-to-face situation.

If the ultimate in objectivity is desired, there is another method that can be used. It consists of inviting a fellow teacher to one's classes periodically for a performance evaluation. As a connoisseur of good teaching (we hope), this person can offer constructive criticism that perhaps will alert the beginning teacher to bad practices of which he was unaware. This may be a somewhat painful process for both parties, and it may not be easy to find a critic who is both willing and able to do a good job. Assuming these difficulties can be overcome, however, this is perhaps the most convenient way of all to get truly unbiased guidance.

There are undoubtedly other ways by which the instructor can find out how to improve. Granted that he *wants* to improve, the important thing is that he realize there are ways he can get objective evaluation of his performance on the job. Subjective feelings may be helpful up to a point, but there is no substitute for "feedback" of the sort outlined above. This is something no education course can provide. It can be obtained in the classroom, true—but only when *you* are the instructor.

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